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ORIGINAL ARTICLES.

I.—On some Crush-Conglomerates in Anglesey.[1]

By Sir Archibald Geikie, D.Sc., LL.D., F.R.S.,
Director-General of the Geological Survey.

THE important observations made by Mr. Lamplugh among the "crush-conglomerates" of the Isle of Man suggest that the phenomena described by him may have a much wider range than had previously been supposed. Ever since I had the opportunity of going over his Manx evidence with him, I have suspected that some of the fragmental rocks which I myself have regarded as volcanic agglomerates might prove to be due, not to volcanic explosions, but to the same kind of underground movements which have undoubtedly given rise to the enormous masses of "crush-conglomerate" in the Isle of Man. The breccias of Anglesey seemed to me likely on renewed examination to prove to belong to the latter series. Accordingly I recently took occasion to revisit these rocks, both in the centre and along the north coast of the island. The result was entirely confirmatory of my suspicions. The breccias in question are, I now feel convinced, true crush-conglomerates.

The amount of mechanical deformation which these rocks have undergone is one of their most obvious characteristics. On the supposition of their volcanic origin it was quite conceivable that coarse agglomerates and volcanic breccias might undergo crushing, together with the sedimentary series to which they belonged, so that this evidence of deformation formed in itself no proof that they were not of pyroclastic derivation. But more detailed investigation, in the light of the Manx examples, brings to view proofs that this conglomeratic structure has been produced by the breaking up of stratified rocks *in situ*. At Llangefni, for example, the strata affected appear to have been originally shales or mudstones (with possibly some fine felsitic tuffs), alternating with bands of hard siliceous grit. They have been crumpled up and crushed into fragments which have been driven past each other along the planes

[1] Read before the British Association at Liverpool.

of movement. Every stage may be traced, from a long piece of one of the grit bands down to mere rounded and isolated pebbles of the same material. The grits, being much more resisting, have withstood the deformation better than the argillaceous strata, which have been crushed into a kind of lustrous slate, or phyllite. Everywhere the signs of movement or "flow-structure" meet the eye. It is not that the rocks have been merely crushed to fragments. The differential movements which produced the ruptures also made the materials to flow onwards, the dislocated bands of grit being reduced to separate blocks and pebbles, entirely surrounded in the moving matrix of finer shaly paste.

The "agglomerates" on the coast near Cemmaes, so singularly deceptive as to be easily mistaken for volcanic necks, prove to be capable of a like interpretation. The huge blocks of limestone, there to be seen isolated among fragmentary grits and slates, are referable to the disruption of some of the limestone bands which occur abundantly in the neighbourhood. A gradation may be traced from the slates and grits outside the areas of more severe dislocation into the intensely crushed and sheared "agglomerate." The dykes which cut through these rocks, and increase the likeness to true volcanic vents, are later than the period of crushing and may be traced in the surrounding slates and grits.

But though the volcanic nature of the rocks believed to be agglomerates must be abandoned, the question of the original formation of the strata which have been so greatly ruptured remains quite distinct. I agree with Mr. Blake in regarding these strata as largely composed of volcanic detritus. The breccias and fine tuffs which alternate with and overlie the Lower Silurian black shales, can be traced upward into the mass of the Amlwch slates, which are full of volcanic dust. The evidence for the existence of Lower Silurian volcanoes in the north of Anglesey remains quite valid and ample, though we must abandon the volcanic origin of the "agglomerates," which seemed to form part of that evidence. The production of the crush-conglomerates has involved the volcanic as well as the non-volcanic parts of the series in the same destruction.

II.—Notes on the Superficial Deposits of North Shropshire.[1]

By C. Callaway, D.Sc., F.G.S.

In studying the rocks of Shropshire, I have paid some attention to the superficial deposits that lie irregularly scattered over the solid strata in the northern half of the county. They had previously been noticed by Miss C. Eyton, in her little book "On the Geology of North Shropshire," while special areas occupied by them have been described by Mr. G. Maw, Mr. C. J. Woodward, and Mr. A. C. Nicholson. Nevertheless, it seemed to me that it

[1] A brief abstract of this paper was read before the British Association, Liverpool, 1896.

would be useful to present a summary of my own observations on the district in question, at the same time incorporating in my notes the most important results of the work of preceding geologists.

I do not propose to enter into the controversy now proceeding between the advocates respectively of land-ice and floating-ice, except in so far as the war has been carried into Shropshire. The facts that I have collected appear to me most consistent with the theory that, in some part of the Glacial Epoch, the Salopian area was submerged to a depth of at least 1100 feet; that during the submergence sandy and shingly deposits were laid down, the materials of which were largely derived from the north; that the marine origin of these beds is demonstrated by an abundant molluscan fauna; and that these deposits were overlain by erratics and boulder-clay, let fall by floating-ice as the floes or bergs melted or capsized. I have not found a single fact inconsistent with this hypothesis, and I have not found a single fact clearly pointing to the former existence in the Salopian area of a great glacier. It is quite possible that, on the flanks of some of the hill-ranges, there accumulated the slight beginnings of glaciers, which carried débris from the higher ground to lower levels; but if such land-ice existed its effects were not very marked.

First, as to the submergence. The deposits with marine shells, found at Gloppa by Mr. A. C. Nicholson, are now well known. They are at 1100 feet above sea-level. They are not to be distinguished from shore deposits now forming at many parts of our coast. The shells they contain are often entire, but they are more frequently broken, as in ordinary littoral sands. The natural interpretation of these facts is, that Gloppa was visited by the sea some time in the Glacial Epoch. That a sheet of ice once scooped up gravels and shells from the bottom of the Irish Sea, and pushed or dragged them to the top of the hills above Oswestry, is a hypothesis that commends itself rather to the intoxication of the theorizer than to the sobriety of the inductive reasoner.

The sands at Ketley, near Wellington, display facts still more hostile to the land-ice theory. The lower part of the section consists of evenly-bedded sands, often clearly ripple-marked. The rippled seams occur one above another to a thickness of some yards, unmistakably indicating a continuance of littoral conditions.

Sand and gravel, usually containing marine shells, are found scattered over the surface of a large part of North Shropshire. At Wollerton, near Hodnet, a gravel-pit displays twenty feet of pebbly beds, with horizontal seams of red sand. *Turritella* and other molluscs are fairly abundant. Besides the ordinary northern erratics, the beds contain large pieces of Lias clay, with *Gryphæa*, *Pecten*, and *Belemnites*. Flints are abundant. In one of them I found a *Rhynchonella*. The Lias specimens are probably derived from the Prees outlier. The flints have been referred to an Irish origin, but of this there is no proof.

At Shrewsbury a large pit on the Severn displays marine sands and gravels of a normal type. They rest on Permian, and are overlain by Boulder-clay. A mile or so north of Shrewsbury, near Almond Park, the shingle is very coarse, rounded fragments up to one foot in diameter being common. Flints are not so abundant as they are further east, which is difficult to account for if they were derived from Antrim.

A good exposure of gravel is seen near Welshampton, not far from the northern border of the county, and is overlain by clay with boulders; but it is needless to multiply descriptions of sections which present so many features in common.

I may remark in passing that I have never found clay under the sands and gravels of Shropshire. Wherever the two formations are seen together, the clay is always uppermost. Strictly speaking, the latter ought not to be described as a clay at all. I have selected specimens of the stiffest material, and triturated them with water in a tall narrow glass, with the result that at least two-thirds of this so-called clay is seen to consist of sand.

I have already thrown doubt upon the alleged derivation of the Chalk flints from Antrim, and should be disposed to refer them to an eastern source. This suggestion receives confirmation from an interesting discovery made some years ago in Wellington. Gravels were being excavated within 100 yards of my house, when the workmen found at a few feet below the surface a perfect specimen of *Waldheimia obovata*. This is a well-known Cornbrash fossil, and must have been conveyed by currents from the south or east.

There is one fact which seems to me absolutely fatal to the views of the advocates of the action of land-ice in Shropshire, and that is the entire absence of the rounding and smoothing ordinarily produced in glaciated districts. I have been working for over twenty years in the county, yet I have never found a *roche moutonnée*. Glacial sands and gravels are found up to nearly the summit of Grinshill Hill, and a boulder of Eskdale granite can be seen on the Longmynd Hills at a height of 1050 feet. The glacier that deposited this boulder, as the land-ice advocates believe, must therefore have entirely submerged Grinshill Hill; yet that elevation is strikingly conspicuous for its angularity. If it be thought that the water-stones of the Keuper were not hard enough to retain a rounded contour, what is to be said for Lilleshall Hill? It stands but slightly above the plain of North Shropshire, and its summit is composed of an extremely hard and flinty felspathic ash; yet the surmounting crags are exceptionally rough and angular. But the time would fail me to tell of Charlton Hill, of Primrose Hill, of the lower slopes of the Caer Caradoc chain and the Longmynd, and of countless crags and elevations which would certainly have retained hundreds of proofs of glaciation had an ice-sheet ever passed over them.

III.—Notes on the Ancient Rocks of Charnwood Forest.[1]

By W. W. Watts, M.A., F.G.S.

(Communicated by permission of the Director-General of the Geological Survey.)

During the re-survey of sheet 155 of the Geological Survey map by Mr. C. Fox Strangways, the writer was instructed to study the ancient rocks where they crop up inside the boundaries of the Trias. The ancient rocks of Charnwood Forest appear in isolated spots, sometimes of considerable size, through the Trias of the Midland Plain. The oldest rock in contact with them is the Carboniferous Limestone of Grace Dieu, which is dolomitized. Evidence as to their exact age cannot, therefore, be obtained from superposition.

They clearly existed as islands in the Triassic and Carboniferous sea, and most probably stood up as mountains on the land in Old Red Sandstone times. The Trias runs up into the hollows and valleys of the old rocks, and from the small amount of débris which extends beyond the margins of the masses it is obvious that the smaller of these, at any rate, have been uncovered at a time geologically very recent. Their features are not those of the present day, but date back partly to the subaerial denudation of Old Red Sandstone and probably earlier times, and partly to the aqueous denudation of Carboniferous and Triassic times. This is the reason for the peculiar character of the surface features presented by the old rock; escarpments are practically absent, hard beds are cut off abruptly, the rocks strike across the ridges, and the landscape generally is not of the usual subaerial character. Present-day denudation, by clearing out the Triassic débris, has done little more than expose to-day a pre-Triassic landscape.

The ancient rocks themselves may be classified as follows, in descending order:—

Swithland and Groby slates Conglomerate and quartzite Purple and green beds	The Brand Series.
The olive hornstones of Bradgate The Woodhouse beds Slate agglomerate of Roecliffe Hornstones of Beacon Hill Felsitic agglomerate	The Maplewell Series.
Rocks of Blackbrook	The Blackbrook Series.

This general succession corresponds with that made out by Messrs. Hill and Bonney, with whose observations the author is in substantial agreement.

These divisions sweep round the semi-dome which is exposed; it is elongated from north-west to south-east, and broken by several longitudinal faults in the same direction. Probably there are some cross faults as well.

The succession is most easily made out in the eastern side of the

[1] An abstract was read before the British Association, Liverpool, Sept. 1896.

anticline, but even here the details are very much complicated, and it is not possible to trace some of the beds for any considerable distance, although the general succession seems quite clear. As Messrs. Bonney and Hill pointed out, the two agglomerates form a most useful index and one which can be traced for a great part of the way round the Forest. The same may be said of the Beacon Hill beds and of the Brand Series.

The bulk of the rocks are made of volcanic ingredients, even the fine hornstones and slates being made of volcanic dust often interleaved with tuffs and breccias. When the lower part of the Maplewell Series is traced round to the north-west it becomes coarser, and eventually passes into a mass of very coarse agglomerates, in which the succession is not easy to unravel, while it is much confused by faulting and the intrusion of igneous rocks; possibly also by the outflow of lava.

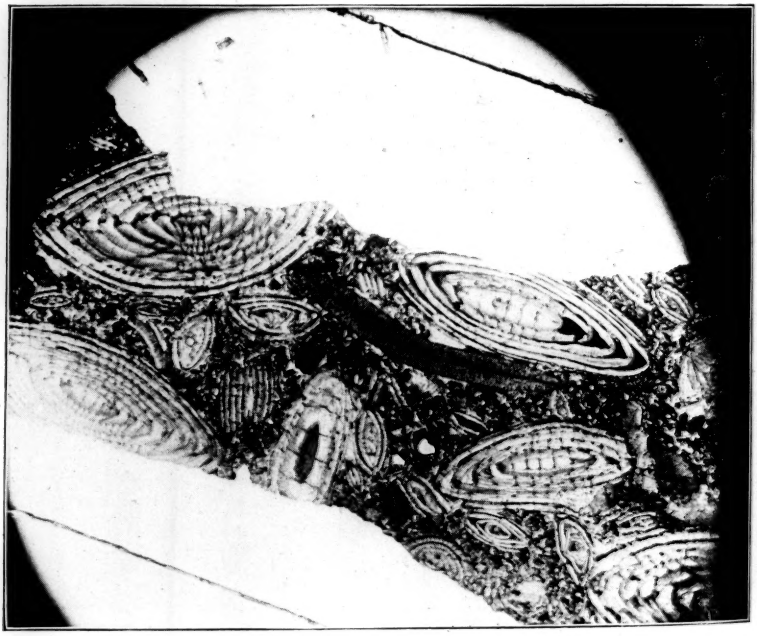
Bardon Hill presents exceptional difficulties. While the chief rocks are like those of Grace Dieu, Cademan, and Whitwick, it lies altogether out of the line of these rocks and must owe its position to faulting. The agglomerates are also associated with a mass of porphyroid like that which occurs in a normal position at Peldar Tor and High Sharpley. At Bardon this rock appears to be intrusive into the agglomerates, and a similar explanation may have to be adopted for Sharpley, Peldar, and Ratchet. Many difficulties would still have to be met, not the least of which is the occurrence of boulders of Peldar rock in some of the agglomerates. A possible explanation of this is found at High Sharpley, where porphyroid, which is now acknowledged to be either an intrusion or a lava, is nodular in structure; it has been subsequently sheared so as to put on the aspect of an agglomerate.

The porphyroids would appear to have been the first rock intruded before much movement had taken place in the rocks; they are sheared, cleaved, and crushed along the north-west and south-east lines.

Syenite was next intruded, generally along the main movement planes such as faults and the junction of the Brand Series with the Maplewell Series. It has been somewhat crushed by the movement, and its main divisional planes agree with the cleavage and faulting directions in the country.

A still later intrusion appears to be the Mount Sorrel Granite, which does not penetrate into the Forest proper, while it is in contact with rocks whose relation to the rest of the Forest has not been ascertained with certainty. It is the only igneous rock which effects any considerable amount of metamorphism in the clastic rocks with which it is in contact.

As to the age of the rocks, we have little to guide us. They are unlikely to be later than Cambrian; they are not at all like the fossiliferous Cambrian rocks of Nuneaton, they do not contain Cambrian fossils, nor do the Nuneaton diorites penetrate them. On the other hand, the movement by which they were affected came from the direction S.W. to N.E., whilst Lower Silurian and Cambrian



Sections of Nummulitic Limestone from Gaza-land, South-East Africa.

rocks are generally, except at Nuneaton, affected by forces which acted at right angles to this.

Professor Lapworth, when with me in Charnwood, succeeded in finding a worn burrow in the slates low down in the Brand Series, and Mr. Rhodes has since obtained one or two additional examples; these are the first undoubted fossils found in the Forest.

IV.—Note on the occurrence of Nummulitic Limestone in South-Eastern Africa.

By R. Bullen Newton, F.G.S.

(PLATE XV.)

THE object of this communication is to place upon record the existence of Nummulitic rocks in South-Eastern Africa; the result of an examination of specimens brought me by their discoverer, Mr. David Draper, F.G.S., of Johannesburg, the enterprising Secretary of the Geological Society of South Africa.

The specimens, comprising two pieces of limestone, were obtained *in sitû* from a spot about 100 miles westward of the mouth of the Busi River in Gaza-land. One is of a light-greyish colour, the other pink or flesh-tinted, and both are crowded with foraminiferal tests in a good state of preservation. Some of the organisms are exhibited in relief on the weathered surfaces, either as sections or exteriors, though for structural details it was necessary to prepare microscopical slides. When these were completed I was able to determine the presence of two rather important species, viz. *Nummulites perforata* and *Nummulites Biaritzensis*, both of which occur in abundance in Madagascar, India, and other localities.

Professor Rupert Jones, F.R.S., who most kindly undertook to examine the sections, not only confirmed my identifications, but was likewise able to point out some other forms, such as *Nummulites Guettardi*, *N. planulata*, and varieties of *Orbitoides papyraceus*. Professor Jones was inclined to regard the *N. perforata* as more closely allied to *N. Ghizensis* of the Pyramids, but as *Orbitoides* is absent in the Egyptian limestone he felt satisfied as to the correctness of the former name. Most of the species referred to are found in the light-coloured rock, the pink material yielding the forms of *N. Biaritzensis* and *Orbitoides*. Both large and small examples of *N. perforata* are present, the former measuring in their longest diameter 15 millimetres, and having an extremely small nucleus; the latter being only three or four millimetres across and possessing very large initial chambers. This difference in the same species forms a good illustration of the phenomenon usually alluded to as dimorphism.

Mr. Draper informs me that there is a large development of this limestone, and although at present without any accurate details of the beds, he hopes soon to return to this part of Africa, when he

intends to re-examine the rocks and to construct a map of the district.

A short time since I called attention to the discovery of Upper Cretaceous strata at Sofala, proved by the occurrence there of *Alectryonia ungulata*;[1] now we have by this new evidence distinct information of the presence of Lower Tertiary deposits, probably capping the Cretaceous formation, in almost the same area of South-Eastern Africa.

The figures accompanying this notice on Plate XV are reproduced from photographs of the sections, whilst the specimens themselves have been kindly presented by Mr. Draper to the Geological Department of the British Museum.

EXPLANATION OF PLATE XV.

Figs. 1 and 2.—Photo-process-reproductions of two thin slices of Nummulitic Limestone (Eocene) prepared by Mr. Frederick Chapman, from hand-specimens obtained by Mr. David Draper, F.G.S., 100 miles to the west of the mouth of the Busi River, in Gaza-land, S.E. Africa, exhibiting sections of the tests of—

Nummulites perforata, De Montf. (Fig. 1.)
,, *Guettardi*, D'Arch.
,, *planulata*, Lamk.
,, *Biaritzensis*, D'Arch. (Fig. 2.)
Orbitoides papyraceus, var., Boubée.

The specimens seen in the sections are magnified four diameters.

V.—Oscillations in the Level of the Land as shown by the Buried River-Valleys and Later Deposits in the Neighbourhood of Liverpool.[2]

By T. Mellard Reade, F.G.S.,
President of the Liverpool Geological Society.

THE geology of the neighbourhood of Liverpool is not on a superficial view very attractive. Nevertheless, to those interested in physical geology it presents some phenomena worthy of careful study.

Treating the subject on Lyellian principles, and proceeding from the latest to the earliest, from the known to the unknown, we have on the coasts of Lancashire and Cheshire an extensive fringe of blown sand. In Lancashire it covers about 22 square miles. In this blown sand I have shown from time to time that many geological phenomena may be studied, some of these being only in miniature. For instance, after a wet season succeeded by wind all the features of cross-bedding as exhibited in the Triassic rocks are beautifully developed in the sand cliffs after they have been cut into by a high tide. Again, sometimes after winter's rain the water, banking up inland against the barriers of sandhills, breaks its bonds

[1] Journal of Conchology, 1896, vol. viii, p. 136.
[2] An abstract read before Section C, Liverpool Meeting of the British Association, 1896.

after reaching a certain level and cuts out miniature river cliffs and terraces and alluvial fans and bottoms.[1] Many other interesting phenomena may be studied which I have no time to deal with here.

The blown sand over its larger area rests upon peat which, appearing on the shore at Alt Mouth, Lancashire, and Dove Point, Cheshire, in turn rests upon Scrobicularia Clays (the Formby and Leasowe Marine beds of my classification[2]). I have found *Scrobicularia in sitû* in the erect position in which they lived in blue clay immediately underlying the peat at both places. I also found, by excavating through the peat at the Alt Mouth, a bed of cockles and other common marine shells at a depth of seven feet. Sewer excavations made under my directions at Birkdale and Hightown proved the continuity of the peat under the sandhills and its connection with the inland peat mosses. In the shore peat are the stools of trees, which are, I am satisfied with most other observers, in the position in which they grew. At the Alt Mouth they were very plentiful twenty years ago, and even so far back as 1796 there is an engraving in the *Gentleman's Magazine*, quite identifiable, exhibiting "Remains of a large Forest near Liverpool." Latterly the peat and trees have been to a great extent swept away by the encroaching tide. Oak was the most abundant, mixed with a great quantity of birch and some Scotch firs. Elytra of beetles are to be found in the peat and many bones of a small species of horse, antlers and bones of the red deer, skull of a *Bos longifrons*, etc. Similar mammalian remains are also found in the underlying blue clays and silts.

These clays and silts—the deposit getting siltier towards the base—in turn rest upon an eroded surface of Boulder-clay, which in certain rare cases has another layer of peat (Lower Peat bed) resting upon it. There is no doubt that the surface of the Boulder-clay represents a land-surface with quite as much certainty as does the Upper Peat, and one that is cut into channels by post-Glacial streams and filled up by post-Glacial deposits.

Underlying all these post-Glacial deposits come the Low-Level Marine Boulder-clays and Sands of Lancashire and Cheshire, which in turn repose upon the Trias, either the Bunter or the Keuper, which may be well studied in quarries about Liverpool. The Low-Level Marine Boulder-clays may be seen in the cliffs of Dawpool on the Dee and in numerous brickworks about Liverpool. The clay is usually of a brown or reddish-brown colour, and mechanical analyses through sieves show various quantities of sand and gravel mixed with clay and flour of rock. Many of the sand-grains are most highly polished and rounded, as also is some of the fine gravel. Mixed with the clay are the remains of numerous shells, of which I have myself collected 44 species, many being of a Northern facies.[3] The clay also contains Foraminifera, and in some places

[1] Science Gossip, 1881, pp. 198–206.

[2] "Post-Glacial Geology of Lancashire and Cheshire": Proceedings of the Liverpool Geological Society, 1871–2.

[3] Q.J.G.S. 1874.

in great abundance. At Cook's Lane, Great Crosby, 3 lbs. of clay yielded to Mr. Joseph Wright 900 of one species, viz. *Nonionina depressula*,[1] and the clay in the cuttings of the Seacombe Branch of the Wirral Railway yielded them plentifully.[2] All these clays contain boulders in varying proportions, mostly of Lake District Silurians, andesitic lava and ash, Eskdale granite and Buttermere granophyre, together with much Carboniferous Limestone and some flints. These are usually planed and striated, often intensely so. Very large erratics of similar rocks are also met with. One now in Sefton Park, dug out of the foundations of a school at Edgehill, of andesitic ash, weighs about six tons. One boulder of Carboniferous Limestone which I got in a brick-pit at New Ferry is bored with *Saxicava*, many of the valves being still in the holes *in situ*. It is also striated. Intercalated in the Boulder-clay are beds of sand and gravel, of which, perhaps, the best-known example is at Blackpool, where the Boulder-clays and sands as proved by boring are nearly 200 feet thick and rest on the Keuper Marls. In connection with the intercalated sand-seams are sometimes to be seen indications of shore action, as in the cuttings of the Wirral Railway before mentioned. Here a sand-bed of a few feet thick is intercalated in the clays and covers a large area. It is full of clay spheres and spheroids, evidently boulders of the Boulder-clay rolled on the beach of sand and sand-coated. Experiments made by Mr. T. W. Davies, F.G.S., show that it was impossible to coat a ball of the clay by rolling it in sand under water, but rolled in damp sand it quickly took up a shield of sand and shell fragments; hence we both of us inferred that the sand-bed represented an ancient shore.

The Boulder-clay, as already observed, rests in this neighbourhood upon the Trias, either Keuper or Bunter, and if the rock be of a nature fit to receive striæ they are usually found upon it, being generally in a north-westerly direction, though they frequently cross each other at an angle even in the same example, and at Millers Bridge I found cross striæ approaching a right angle. If the rock be soft it usually either grinds into sand or sand and rubble. I have never succeeded in finding a boulder lying upon the rock of which it could be said the striæ were due to it, but this may arise from the difficulty of making the observations. The surface of the Triassic rocks under the Boulder-clay without doubt represents a land-surface still older than the land-surface at the top of the Boulder-clay or that of the peat and forest bed. The evidence of this is the subaerial erosion which has shaped its orographic forms and the river-channels now filled up with Boulder-clay which ramify below the present surface. Such a pre-Glacial valley was proved to exist in the Mersey filled with Boulder-clay, which was predicted by me in 1873, and proved by the Mersey Tunnel twelve years afterwards. If the clay and sand deposits were

[1] "Foraminiferal Boulder-clay, Great Crosby": Proceedings of Liverpool Geological Society, Session 1895–6.

[2] Proceedings of Liverpool Geological Society, Session 1894–5.

stripped from the Triassic rocks, we should behold a landscape of a much more varied character than that which we now see.

If, as I have endeavoured to show, the geological facts related prove the existence of *three land-surfaces*, the first in time being pre-Glacial or, at all events, pre-Boulder-clay, and cut in the Triassic rocks, the second post-Glacial, represented by the buried eroded surface of the Boulder-clay, and the third indicated by the peat and forest beds, it is evident that there have occurred a good many variations in the relative levels of land and water. In the first or pre-Boulder-clay period, taking into consideration the known depth of many buried valleys, it is highly probable that this was a Continental period, with all the British Islands, united, and the various rivers converging into one large river traversing the basin now occupied by the Irish Sea, and delivering its waters into the Atlantic through the Straits of Galloway, where there is a "broad ditch" 600 feet below the general level of the bottom. The land then sank beneath the waves, and the marine Boulder-clay was deposited.

Certain supporters of land-ice as against every other cause maintain that there was no alteration of the relative level of land and sea at this time, but that the low-level marine boulder-clays and sands and the high-level sands and gravel are simply sea-bottom swept on to the land by an ice-sheet advancing from Scotland over the Irish Sea bed. Suppose we grant this contention, which 25 years' observations has led me to reject, the pre-Boulder-clay valleys running down to a level far below low-water remain unaccounted for, and it is necessary still to postulate a pre-Boulder-clay elevation of the land to account for these river-channels eroded in the Triassic rocks. If we admit this reasoning, and I see no escape from it, the *a priori* assumption against the probability of a movement of submergence during the Glacial Period, of which, I maintain, the whole of the marine glacial deposits up to 1400 feet are indicative, is knocked off its feet. The first period of oscillation, then, is represented by a high-level land-surface, followed by a subsidence of a river-valley system below the waves, and, I maintain, by a still further depression of 1400 feet during the deposit of the low-level marine boulder-clays and high-level sands and gravels containing marine shells.

The second period of oscillation represents an emergence of the sunken land from its extreme depression to a level above the sea considerably greater than we see now. In a minor manner stream and river valleys were cut in the Boulder-clay similar to those of the previous period. In the third and last period of oscillation a depression of the land again occurred to the 25-feet contour, and the post-Glacial silts and Scrobicularia clays were laid down upon the eroded surface of the Boulder-clay with its minor valley system.

Again a reverse movement took place, the land being elevated above its present level, allowing the growth of forest trees now swept by the tide, and finally these were submerged by the last downward movement of the land.

That this in outline is what geological history tells has happened in the neighbourhood of Liverpool, I have no manner of doubt. Similar movements of the land, not necessarily in this order or of the same frequency, are registered all round the coasts of England and Wales, Scotland and Ireland, as shown by dock or other excavations where the submarine geology can be explored.

Whether my hearers agree with me or not in the details of these land movements, he would be a bold man who would deny that they have occurred on a large scale during the periods named. Admitting the fact, the interesting question remains, what is the cause of these frequent oscillations of level. One favourite explanation at the present time is that it is the effect of isostacy, of a loading and unloading of the earth's crust by sedimentation and denudation. Let us examine this: the glacial deposits cannot average so much as 200, probably not 100, feet in thickness; the effect of such a loading would be inappreciable on the earth's crust, whatever view we take of the constitution of the earth's interior. If the addition of the glacial deposits cannot affect the foundations of the earth, still less can their partial denudation create a rise of land. The same reasoning applies with greater force to the post-Glacial deposits, as they are neither so extensive nor so massive. Alterations of the sea-level seem to me out of court, simply because such fluctuations must arise from gravitation to land masses, thus creating a greater difficulty to account for a lesser one, as the land masses have to be moved first before the water of the sea can follow.

Mr. Shone has suggested that the subsidence of the peat and forest beds has been due to subterranean erosion, but they occur at too regular levels and in too many places to render this a feasible explanation. Ice in the Glacial Period accumulating in great thicknesses on the land has been appealed to as a cause of submersion, and its melting of emergence. This is a more plausible suggestion, because there is nothing to bind us in our idea of the load, which we can pile up in imagination to any extent, but unfortunately it does not explain post-Glacial movements which are demonstrated to have taken place, not only by the facts I have laid before you, but by the shore terraces found in various places around our Islands.

It appears, then, that these pulsations of the land are not due to external causes, but to causes hidden from us in the earth's interior.

VI.—On the occurrence of Corundum produced by Contact-metamorphism on Dartmoor.[1]

By Professor K. Busz.

SOME three years ago, when travelling in Devonshire, I had the opportunity of visiting some places on Dartmoor, and of collecting on the border of the Dartmoor Granite some specimens of rocks, which on closer examination seemed to be of general

[1] An abstract of this paper was read before the British Association, Liverpool, September, 1896.

interest. Although I have not finished the examination of these, yet I have made some remarkable observations, which I should like to describe to the readers of this Magazine.

It is well known that the Dartmoor Granite is the largest of the numerous granite exposures of Devon and Cornwall. As to its origin and age, there have been brought forward very many different views and theories. Whatever these may be, it is, I suppose, generally understood that this granite-mass is of post-Carboniferous age. The Devonian, as well as the Carboniferous strata and their interbedded contemporaneous igneous rocks, have undergone great alteration at their zone of contact with the granite.

The place I visited, where these alterations are well exposed, is near South Brent, on the south end of the Dartmoor Granite, where a little stream, the Avon River, cuts right through the contact-zone.

The rocks affected by the contact-metamorphism are of different characters. I found Devonian clay-slate altered into chiastolite-slate and spotted mica-slate, while small seams of interbedded limestone have given rise to the formation of garnet and other minerals.

I may mention here that I found close to South Brent on the right side of the Avon River one of these limestone-layers, of about two yards' width, almost entirely changed into garnet. This garnet, grossularia (calcium-iron-garnet), is of a light-brown colour, and either shows the very well-developed form of the dodecahedron or occurs in granular masses with no distinct crystallographic form; it shows a very strong, anomalous, double refraction, and also very distinctly the partitioning into sectors described by Professor Klein. The crystals are sometimes imbedded in a saccaroid-grained white mineral, which chemical analysis proved to be the lime-felspar anorthite. Besides these, malacolite and axinite occur abundantly in this locality.

It may perhaps be of interest to mention that I have found Cassiterite to be present in some of the andalusite-bearing schists. It occurs not only imbedded in the long-shaped crystals of andalusite but also in the groundmass of the rock, and exhibits well-defined crystalline forms, which very often show the well-known twinning. By the aid of hydrofluoric and hydrochloric acid I succeeded in isolating these crystals for chemical analysis.

All these alterations of the schists surrounding the granite, which we may call exomorphous contact-metamorphism, are of course very common, and can be observed more or less intensely developed in every granite-mass. Not so common, but, on the contrary, rather rarely observed, is endomorphous contact-metamorphism, and it is the latter to which I desire to draw the attention of your readers.

In the above-mentioned locality I found in close contact with clay-slate a felsitic porphyry, which, in a light grey-coloured groundmass, contained a few small but rather well-defined crystals of plagioclase. One specimen which I was able to collect consists, one half of this felsitic porphyry, the other half of clay-slate altered into black hornfels. The latter is very much broken,

and the irregular-shaped pieces are surrounded by felsitic matter. The microscopic examination showed that the felsite contained a great number of very small colourless crystals, which sometimes show distinct hexagonal outlines and contain minute black inclosures. These crystals accumulate round the pieces of clay-slate, and decrease in number the further away from the slate one examines the slice. I have for some time been very much puzzled as to what this mineral could be. By dissolving a portion of the rock in hydrofluoric and hydrochloric acid a white powder remained, which under microscopic examination proved to consist solely of the crystals in question. By analyzing these I found nothing but alumina and very small traces of iron-oxide, probably due to the minute black inclosures, which I suppose to be magnetite.

I then tried to determine the hardness. I put a little of the powder between two cleavage-flakes of topaz, which after a little rubbing soon lost their lustre and became perfectly dull. There can be no doubt, therefore, that the mineral in question is corundum; and also, considering the manner in which it occurs, that it is not an original constituent of the felsitic porphyry.

My belief in regard to the origin of this corundum is this, that the eruptive rock, when the eruption took place, partly dissolved and absorbed the broken pieces of the clay-slate, and that afterwards in this felsitic matter, which was then supersaturated with alumina, the crystallization of the corundum took place on cooling.

We are aware of the fact that corundum as a product of contact-metamorphism is very rare, and has, indeed, only lately been described in one or two cases, which, however, are quite different from the occurrence on Dartmoor. I therefore thought it would be of some interest to record this discovery, all the more as it is, so far as I know, the first instance of the occurrence of corundum in this way in the British Islands.

VII.—On the occurrence of Sillimanite Gneisses in Central Anglesey.[1]

By Edward Greenly, F.G.S.

In the course of some traverses of the central region of Anglesey recently made, preparatory to mapping it out in detail, I observed a few facts which, in spite of the evident complexity of the structures, can, I think, be safely described before completion of the map, and are of some interest in connection with other recent researches in gneissose areas.

The region in question (see descriptions by Sir A. C. Ramsay, Dr. Callaway, the Rev. J. F. Blake, Sir A. Geikie, and others) extends across the island in a north-easterly direction from Llanfaelog to near Llanerchymedd.

To the south-west of the Holyhead Road granite appears to occupy the greater part of the surface, but to the north-east a complex system

[1] An abstract of this paper was read before the British Association, Liverpool, September, 1896.

of gneissose rocks is associated with the granite. Some of these, as about Craig yr Allor, are banded hornblendic gneisses and foliated diorites, whose strong resemblance to much of the Archæan gneiss of the North-west Highlands of Scotland has been pointed out by Sir A. Geikie.

But in the neighbourhood of the Holyhead Road the coarse granites can be seen in contact with quartzose and micaceous schists. The junctions are very clearly intrusive, the granite often passing quite abruptly across the foliation planes of the schists, and containing many included fragments of them. More frequently, however, the relations are those of sills, the granite lying between parallel folia, or passing across them at very gentle angles. Moreover, the schists contain, close to their junction with the granite, thin seams of quartz, which are full of fine needles of sillimanite, forming thoroughly characteristic "Faserkiesel." The granite shows no sign of chilled edges, being, so far as I have yet observed, quite as coarse at the junction as elsewhere. The phenomena are, in fact, very closely allied to those described by Mr. Barrow in the S.E. Highlands of Scotland, and also in a paper by Mr. J. Horne and myself, read before the Geological Society of London, on June 10 last, on "Foliated Granites and their Relation to Crystalline Schists in Eastern Sutherland." Fine granulitic quartzose schists, containing idiomorphic magnetite, also occur.

Although sillimanite occurs in certain seams in the schists close to the Holyhead Road, it does not appear to be abundant; and the crystalline texture of the schists is, on the whole, rather fine. But a little distance along the strike, to the north-east, the whole series of phenomena become much more pronounced. Coarse, wavy gneisses appear in which sillimanite is abundantly developed, knots and irregular seams of hard, pale sea-green "Faserkiesel," full of fine, lustrous needles, being conspicuous on their rugged, weathered surfaces. Innumerable granite bands and lenticles are interfelted with these gneisses, exactly as in Eastern Sutherland,[1] and synthetic gneisses of the same type occur all along the strike to the neighbourhood of Llanerchymedd. The beautiful biotite gneisses of the inlier at Tafarn-y-botel (whose resemblance to rocks of the Scottish Highlands has been noticed by Mr. Blake) are almost identical in character with those of Kinbrace, in Sutherland, a region of excessive metamorphism and intimate granitic injection. Sillimanite is of frequent occurrence, being sometimes included in the micas, which are large and well developed. The thin granitic seams contain large and beautifully striated oligoclase.

The whole series of phenomena closely correspond with those of Eastern Sutherland, and I have little doubt that they are of essentially the same nature. Certain rock types occur, however, which have not yet been observed in the latter country.

[1] In the recognition of these peculiar modes of granitic injection will, I think, be found a reconciliation of the conflicting views that have been held as to the intrusive or "interbedded" character of the granite. I should like also to draw attention to the very vivid and faithful description of these phenomena by Sir A. C. Ramsay ("Geol. North Wales," ed. 2, p. 243).

The progress of the mapping (a small part only of which is completed) will, I hope, throw light upon the relations of this highly crystalline series to the schists of undoubtedly clastic origin which occur in the island, as well as to those basic gneisses of Hebridean or Lewisian aspect which appear to form part of the same foliated complex.

VIII.—Recent Borings in the Red Marl, near Liverpool.[1]

By G. H. Morton, F.G.S.

Boring in the Red Marl near Altcar, North of Liverpool.

DURING the years 1890–2 an important boring was made in the Red Marl, rather under a mile NNE. of Altcar and nearly two miles east from Formby station. Previous to 1890, the formation was supposed not to exceed 400 feet in thickness, the amount proved at Birkdale many years ago. The following is a section of the strata passed through, condensed from details for which I am indebted to Mr. E. Fidler, who was connected with the undertaking :—

	Ft.	in.
Peat	5	0
Loam and sand	28	6
Boulder-clay	16	0
Sand and marl	8	6
Red Marl	971	0
Keuper Sandstone	62	0
	1,091	0

The diamond boring machine was used, and the diameter of the borehole was thirteen inches near the surface, seven and six inches through most of the Red Marl, and five inches in the Keuper Sandstone. The dip of the strata was supposed to be a few degrees to the north-east, as determined by the cores brought up. The marl separated with thin laminæ, and the surfaces were often covered with pseudomorphic crystals of chloride of sodium from an eighth to an inch across, and they were most numerous in the middle and lowest beds. There were many seams of gypsum, which varied in thickness from a quarter of an inch to three or four inches, and a few diagonal cracks filled with the same mineral traversed the beds, and often contained fragments of marl and presented a brecciated appearance. The surfaces of the cores of gypsum exhibited pseudomorphs like those on the marl. Most of the marl was red, but sometimes a greenish grey, and the lower beds contained the tracks of annelids, which have been found on the same horizon in several other places in Lancashire and Cheshire. The Keuper Sandstone below the Red Marl was red and grey in colour, and there was an abrupt change from one formation to the other without any transitional strata between.

The object of the boring was to find brine or rock-salt, but it was unsuccessful, and the attempt was made in consequence of a

[1] An abstract read before the British Association, Liverpool, September, 1896.

tradition that prevails in the neighbourhood that salt water occurs below the surface. Mr. J. Dickinson, F.G.S., in his Parliamentary Report on "The Salt Districts," refers to a brine spring mentioned by Dr. Browning; and Baines, in his "History of Lancashire," states that it "contained as much salt as that at Northwich." Mr. Fidler informed me that though salt water has been frequently found near the surface in various places in the district, fresh water was found on penetrating to a greater depth.

I am inclined to think that the salt water found about the surface of the country is in consequence of frequent floods from the sea in former years, and the deposit of spray during storms. The wind carries the fine spray for many miles inland, and a film of salt has been found coating windows at a distance of twenty or thirty miles from the sea after storms, so that it is certain to impart a saltness to the soil over the land along the coast.

Boring in the Red Marl at Ford on the West of Bidston Hill.

Another boring in the Red Marl has been in progress during the last two years on the east bank of the Fender, a brook running from south to north into the Birket and finally into Wallasey Pool. The object of the boring was to obtain an additional supply of water for Birkenhead, and I am indebted to Mr. W. A. Richardson, C.E., for the following section of the strata passed through :—

	Feet.
Surface-soil	1
Boulder-clay	45
Sand and gravel	16
Red Marl	454
Keuper Sandstone	244
Fault rock	7
Upper Soft Sandstone of the Bunter...	133
	900

The boring was made with a revolving iron disc with steel chisels, two feet in diameter, suspended by a flat rope, but the cores brought up were only four inches across, most of the rocks having been broken into fragments, sand and clay. The cores showed that the strata were horizontal. The Red Marl was found to be much harder than usual, and principally composed of tough argillaceous sandstones and shales nearly all of a red colour. Very little gypsum was found, and the entire absence of pseudomorphic crystals was remarkable. It seems probable that the deposit was formed in deeper water than the Red Marl at Altcar.

At Greasby, a village two miles west of the boring, there are some beds about two inches thick containing small ramifying tube-like cavities from $\frac{1}{40}$ to $\frac{1}{60}$ of an inch in diameter. They have been supposed to be at the base of the Red Marl, but were found at several horizons in the boring, and evidently do not indicate the base, so that the beds at Greasby may be considerably above it. The Red Marl ended at the depth of 516 feet below the surface, so that

deducting 62 feet for the superficial deposits the thickness is 454 feet, being about double the amount it was expected to be. There was an abrupt change from the Red Marl into the underlying Keuper Sandstone, which was penetrated to the depth of 244 feet, when a fault was crossed and the Upper Soft Sandstone of the Bunter proved to the depth of 133 feet.

The Geological Survey Map of the district (Sheet 79, N.E.) distinguishes the Red Marl from the "Waterstones" at the base over the centre of Wirral, but it does not seem possible to have made such a distinction in South-West Lancashire, where both are included in the Red Marl. At Ford most of the marl is of an arenaceous character, while on the east of Liverpool the beds are softer and include more shale and clay. It seems, however, that the Keuper Sandstone in Wirral is of less thickness than it is under Liverpool, and that the upper beds there are represented by the "Waterstones."

IX.—The Great Submergence: an Interpretation of the Clava Section, near Inverness, Scotland.[1]

By John Smith, Monkredding.

THE interesting section at Clava, near Inverness, was first examined geologically by Mr. James Fraser, C.E.; and his remarks on it were published in the Transactions of the Geological Society of Edinburgh, vol. iv, part 2, and in the Transactions of the Inverness Field Club, vol. ii.

As this section contains a thick bed of shelly clay situated at a height of 503½ feet above sea-level, it has become, owing to its uniqueness[2] in Scotland, of the very greatest interest to geologists, so much so that it has been examined and reported on by a committee appointed for the purpose. The finding of the majority of the committee has been that the shelly clay is in position, as it was deposited on a sea-bottom. The minority (Mr. D. Bell and Mr. P. F. Kendall) think that the shells were carried uphill by ice from Loch Ness, then an arm of the sea. I throw in my lot with the majority, and shall give my reasons for doing so.

At the invitation of Mr. Bell I had an opportunity of examining the section, and spent part of a day there when the Committee made one of their visits to Clava. This was at the time when the large pit was dug, and there was an excellent opportunity of inspecting the section, and especially the shelly clay.

The section at the main pit, as published by the Committee, is as follows, the lower part having been ascertained by boring:—

	Feet.
1. Surface-soil and sandy boulder-clay	43
2. Fine sand (stratified, yellowish-brown)	20
3. Shelly blue clay with stones in lower part	16
4. Coarse gravel and sand	15
5. Brown clay and stones	21½
Solid rock, Old Red grit.	

[1] Read to the Geological Society of Glasgow, February 13, 1896.

[2] Since this was written I have discovered in Ayrshire very numerous exposures of shelly clay at various levels, from a little above high-water mark to 1061 feet above sea-level.

A few sentences may here be given from the report of the Committee—

"The highest part of the shelly clay in the 'main pit' is 503½ feet above sea-level. The deposit is 16 feet thick in that section, and appears to be continuous for a distance of at least 190 yards in a well-nigh horizontal position." . . . . "It contains a small proportion of stones usually well-rounded and chiefly near the base." . . . . "The shells are chiefly shallow-water species; some might have lived at a depth varying from 15 to 20 fathoms[1] . . . but the majority are littoral forms." . . . . "The shells on the whole are remarkably well preserved, many retaining their epidermis. They are neither rubbed nor striated." . . . . "The pressure of the ice that formed the overlying 43 feet of Boulder-clay would be sufficient to account for the crushing of certain shells, the compression of the annelid tubes, and the production of the system of cracks in the clay."

These quotations agree perfectly with what I myself observed at the Clava pit. I will now first attempt to show, having regard to the facts of the case, that it is physically impossible that the shelly clay with stones, or even the shells, can have been transported uphill by ice.

Stones may be carried long distances by ice, even uphill, without being striated, but they must fall on the surface of a glacier. The moment a stone reaches the bottom of the ice it will begin to be striated. The shelly clay cannot possibly have fallen on the surface of the ice, neither could it have been carried up *under* it without many of the shells (if not all, in this case) having been striated. *Now, not a fragment of a striated shell has been found in the shelly clay.*

Neither are the stones in the shelly clay striated. This point I can myself attest, as I superintended the washing of the stones from which the percentages were taken, and only *three* of them showed *faint* striations, two of the stones having been obtained when I was present. A stone striated on *one* side had the mark of attachment of a *Balanus*. It cannot therefore possibly have been striated *after* the *Balanus* had grown on it. It was more likely to have been a scratched stone washed out of the Lower Boulder-clay

[1] In the body of the report it is stated that some of the species still live at 100 fathoms.

I asked Mr. J. T. Marshall, of Torquay, one of the authorities on recent shells, to give me the depths at which some of the species found in the Clava section still live, and he has furnished me with the following information:—

Astarte compressa	3 to 2000	fathoms.	
,, sulcata	3	400	,,
Leda pernula	5	210	,,
,, tenuis (pygmæa)	0	240	,,
Nucula tenuis	3	365	,,
Tellina calcarea	0	128	,,
Natica Grœnlandica	2	1290	,,
Pleurotoma turricula	10	150	,,
,, Trevelyana	6	189	,,
Trochus Grœnlandicus	0	150	,,
Trophon clathratus	3	530	,,

during the subsidence, from which the striæ had not been wholly removed by subsequent attrition.

As no one holds the opinion that the shelly clay was transported *en masse*, this point need not be discussed. I merely remark that we see how Carboniferous shale which had been torn up by a glacier may be drawn out into a *long thin band* before it travels many yards. This would be the fate of any shelly clay adhering to the bottom of a glacier.

Mr. Bell, in his paper published in the GEOLOGICAL MAGAZINE in July, August, and September, 1895 (pp. 321, 348, and 402), offers the following explanation of the mode of formation of the shelly till. He says: "We have said that, if transported by the ice, it does not 'necessarily follow' that the whole of this deposit was conveyed simultaneously, or *en masse*. Briefly, our idea is that it may have been conveyed very gradually, and deposited in an *extra-glacial* lake, formed at this point along the side of the ice-sheet, into which part of the materials being carried by the latter (fine mud, rounded stones, shells, etc.) dropped and were accumulated."

I have already stated that it is physically impossible that part of a sea-bottom could be taken up and carried forward by ice (in the Clava case the marine material would require to have travelled over "hill and dale" some ten miles) without the shells being striated. We have plenty of shelly tills that have been dragged a bit by land-ice, but in them the shells (nearly always fragments) are mostly striated. Two stones from the shelly clay had several *Balani* attached to them, and three others had marks of the bases of *Balani* still upon them. Some of the shells of *Astarte* had both valves *in position*, but crushed.

But for argument's sake let us suppose that the ice has delivered its burden at Mr. Bell's hypothetical lake some 500 feet above the present sea-level, or some 400 feet above the then sea-level, for Mr. Bell's hypothesis demands a small subsidence. In the first place, the stones (now in the shelly till) would require to have had their striæ removed, which could only have been done by being rolled in water. (They are all well-rounded stones, and could not have fallen *as splinters* from a cliff upon the top of a glacier.) Now the Clava shelly clay says—"No, this cannot have been the case. *I am a mud; there were no currents flowing where I was laid down*; there is not a single line of stratification in me." In the second place, there would be water flowing through this hypothetical lake which would cause the deposits to be stratified. And there would be the further impossibility of substituting *complete* for broken and scratched shells.

It is clear, then, that this deposit (the shelly clay) could not possibly be formed in this way; it is a deep-water deposit formed in the sea where there were no *bottom* currents. Had it been formed in an upland tarn it ought to have contained abundance of vegetable matter, fresh-water mollusca, fresh-water diatoms, fresh-water Ostracoda, etc.; *but there is not a vestige of anything organic in it that is not marine.*

The fossils from the shelly clay may be tabulated as follows:—

	Species.	
Mollusca	24	
Decapoda	2	
Cirripedia	1	
Ostracoda	24	
Annelida	1	
Foraminifera	36	
Total	88	All *marine* species.

I will now give my own interpretation of the Clava section, commencing with the lowest bed.

Bed No. 5 is described as "brown clay and stones," and is probably the Lower Boulder-clay, but as it is only known from boring, nothing further need be said about it.

Bed No. 4 is composed of coarse gravel and sand. I shall call it the basal gravel of the Interglacial Period, and explain my reason for this. When a country is sinking below the sea, the shore waves constantly agitate the material they come in contact with, washing out the mud and forming gravels and sands. These may in time form what are known as *basal conglomerates*, from being found at the bases of the great formations. This bed, then, I take to have been formed by the waves when the land was sinking. It may originally have contained abundance of shells, etc., but in such loose material fossils are seldom preserved.

On the top of it comes the *shelly clay*, 16 feet in thickness, with stones up to six inches in diameter, mostly in the lower part. It has no stratification, no bedding-planes; the stones cannot, then, have been rolled into it by bottom currents.[1] If they had been so derived it would have been a *gravel* bed instead of a mud bed with stones; currents strong enough to have rolled along stones from two to six inches in diameter would have swept away all the muddy material.

The shelly clay has been formed in deep water by *surface currents* carrying muddy water, and thin shore-ice carrying mud, sand, stones, and littoral species of shells. It also contains ten species of shells that may have lived at a depth of 150 fathoms; and as many of those which have lived at moderate depths may have been cast ashore and caught up by the shore-ice which carried the stones, there is no difficulty, in this view, of seeing how shells which lived at different horizons may have been commingled in the Clava shelly clay.

The next bed is composed of fine stratified sand, with some very small stones. It is 20 feet in thickness, and is yellowish-brown in

[1] At a depth of 3½ feet in the clay a horizontal line was observed, and at 6 or 7 feet streaks or thin layers of sand and gravel were seen, but these do not at all affect the argument. There was also a transition bed of 2 feet in thickness at the bottom of the shelly clay, with a well-defined bedding-plane between it and the gravel bed below, the 2 feet bed being mixed with fine gravel.

colour. It has been formed by bottom currents, and has every appearance of a sand that was at one time filled with shells which have been dissolved away by acidulated water. It is, in fact, what is known as a "rotten sand."

At page 14 of the report it is stated that spines of *Echinus* and *Spatangus* were obtained in No. 6 bore at a depth of 21 to 24 feet, in hard-bound sand. This may have been the same bed as the above.

The top bed is *sandy* Boulder-clay and stones, of the great thickness of 43 feet, and I take it to be a ground moraine[1] of the second glaciation.[2]

I have now only to add that when the glacial deposits (drift formation) receive a closer examination than has hitherto been given to them, many more proofs of their marine origin will, I think, be forthcoming. The most accessible exposures are the scaurs of drift along the stream courses, and I seldom return from a day's examination of them without finding additional proofs of the *whole drift formation* having been deposited in the sea.

X.—Notes on the Globigerina Limestones of the Maltese Islands.

By John H. Cooke, F.G.S.

THE Globigerina Limestones of the Maltese Islands consist of a series of beds of varying character, the upper portions of which belong to the Lower Langhian, while the lower are referred to the Upper Aquitanian. The formation extends throughout both islands, but in the north-western and western portions it is masked by overlying beds of clays, greensands, and limestones, of Tortonian and of Helvetian age.

The Maltese Langhian may be divided, lithologically, into two well-marked sub-series—the upper, which includes the "Marls and Clays," and extends from the base of the Greensands to the top of the Globigerina Limestones; and the lower portion, which includes the beds A to F of the "Globigerina" series. Palæontologically both divisions agree closely, and contain such characteristic Langhian forms as *Aturia aturii* and *Pecten denudatus*. The palæontological analogies of the two groups are shown in the synoptical table of fossils at the end of this paper. The total thickness of the formation ranges from 150 feet to 250 feet.

Regarded vertically the following tabular summary gives the serial order and the thicknesses of the subdivisions.

[1] From what I have since seen in Ayrshire I have been obliged to abandon the idea that the Boulder-clays are *ground moraines* pure and simple. I think there is ample proof that they are *marine deposits*. In places where they have been *dragged* a bit by the last glacier-ice they become ground moraines.

[2] It is not here argued, of course, that during the period between the two Boulder-clays the country was entirely free from ice.

THE GLOBIGERINA LIMESTONES.

Sub-division.	Lithology.	Thickness	Series.	Equivalents in Vienna Basin.
A	A ferruginous, argillaceous freestone.	15 to 30 ft.	Langhian.	Horner Schichten
B	First seam of phosphatic nodules.	1 foot.		
C	A fine-grained, bluish freestone.	30 to 50 ft.		
D	Second seam of phosphatic nodules, with smaller seams above and below locally developed.	1 to 2 ft.		
E	Fine-grained limestone, with several bands of phosphatic nodules locally developed.	35 to 50 ft.		
F	A massive, compact limestone, with chert nodules.	30 to 50 ft.		
G	Third nodule seam.	1 to 2 ft.	Aquitanian.	Solsza-Schichten
H	A variously textured limestone, with phosphatic nodules sparsely distributed.	50 to 80 ft.		
I	Fourth seam of phosphatic nodules.	2 to 4 ft.		

Bed A.—The "Marls and Clays" that overlie this formation graduate downwards into a close-textured, fine-grained freestone, the upper portion of which contains from 25 to 30 per cent. of alumina, but towards the lower part this percentage decreases until the ratio of alumina to calcium carbonate is as 1 to 9. The bed is variously coloured, the upper layers being generally of a bluish-grey, and the lower part of a light-yellow or yellowish-ashen colour. Iron pyrites abound, and it is to the decomposition of these that the tinctorial variations are due. Organic remains are plentiful, but as a rule they are so pseudomorphed with either peroxide or phosphate of iron, as to be barely recognizable. The carbonate of lime, of which the shells were originally composed, has been wholly or partially replaced by carbonate of iron, and this, by subsequent oxidation, has been converted into a hydrous peroxide. The pyritized condition of the fossils is a feature of this bed. The most prevalent and characteristic forms are *Aturia aturii*, *Pecten Koheni*, *Pecten denudatus*, *Chenopus pes-pelicani*, *Dolichotoma cataphracta*, *Nuculana fragilis*, and *Marginella Deshayesi*. Many forms of the Gorgonidæ,[1] e.g. *Isis Peloritana*, *I. Melitensis*, and *I. compressa*; the claws and carapaces of *Cancer macrocephalus*; and the tests of pteropods, chiefly *Vaginella* and *Hyalæ*, invested in thin metallic-iron coverings, are also numerous.

The *Scalariæ*,[2] which make their first appearance in division F, and are continued in the successive beds up to the "Marls and Clays," are here represented by the minute form *S. Melitensis*, Fuchs.

[1] For the determination of the Gorgonidæ I am indebted to Professor Angelli, Università di Roma.

[2] Mr. G. F. Harris, F.G.S., kindly determined the *Scalariæ*

Of the Echinodermata, *Echinocyamus Studeri*, *Echinolampas Manzoni*, *Hemiaster vadosus*, *Sarsella anteroalto*, and *Schizaster Parkinsoni*, are found here and in the underlying divisions B, C, and D.

At this horizon lignite is of common occurrence. Mr. N. Tagliaferro described a piece, in the pages of the *Mediterranean Naturalist* for June, 1893, that measured 11 ins. × 4 ins. × 1 in., and which a microscopical examination showed to be the outer layer of a tree-trunk.

Division B: the first nodule seam.—A seam of phosphatic nodules forms the base of the limestones of division A. The cliff exposures along the southern shores of Malta show this seam to average about 9 inches in thickness, and the nodules are small and sparsely distributed. But in the hill escarpments of Emtarfa, Wardia, Boschetto, and Hempsia it averages 15 inches, and the nodules are large, numerous, and compactly cemented together in a phosphatic paste. Most of the nodules and the fossils found with them are of a jet-black colour, and they have a high, metallic lustre. In composition they vary from the nodules contained in the underlying seams, being composed for the most part of phosphate of iron. Of the fossil organisms the corals are a noteworthy feature. The following species occur in abundance: *Trochocyathus lateroristatus*, *T. pyramidatus*, *Flabellum avicula*, and *F. intermedium*. All of these species have a considerable vertical range, being also found in the Tongrian of Dego, the Helvetian of Torino, of Belforte, and of Val Salice, the Tortonian of Tortona and of Stazzano, and in the Pliocene of Zinola. In the Maltese Islands they occur in the subdivisions A to I.

Division C.—This bed consists of a variously textured rock, having a reddish-yellow colour. The upper portion is coarse and susceptible to weather influences; but it merges imperceptibly into a fine-grained, compact limestone, massive and homogeneous, and with a total absence of the tendency to cleave which characterizes the coarser variety. Small concretionary masses of hæmatite and chert frequently occur, and when the rock is cut through they appear on the slabs as black or red blotches which are known locally as *suaba* or finger-marks. Thin layers of phosphatic nodules are locally developed at Fom-ir-Rieh, but they seldom extend far. The fauna of the bed is similar to that of B and D; but several fossils of note occur in it that are deserving of mention. A portion of a carapace of turtle, *Tryonx Melitensis*, Lyd., was obtained by Mr. G. Gollcher; a fragment of the symphysial part of the slender mandible of ?*Ichthyosaurus gaudensis*, Hulke, was exhumed at Marsa Forno; the greater portion of the jaws of *Tomistoma champsoides* and the remains of numerous crocodilians and whales have been obtained from this horizon by Adams and others.

The Brachiopoda are here well represented by *Terebratula caput-serpentis*, *T. minor*, and *T. Cortæ* var. *parumlobata*, De Greg.

Division D: the second nodule seam.—This bed consists of an aggregation of irregularly-shaped nodules, intermixed with enormous quantities of the phosphatized remains of molluscs, echinoderms,

crustaceans, corallines, fish, and cetaceans. It has an average thickness of about 18 inches, and it is very uniform in its general physical and chemical aspects. The interstitial cement contains about 2 per cent. of phosphoric anhydride, all of which is found in combination with iron, alumina, or lime. These nodules contain a much higher percentage of alumina and of iron than do the nodules of seam iv.

The following analysis shows the composition of the nodules of this seam :—

Carbonate of lime ($CaCO_3$)	40·24
Sulphate of lime ($CaSO_4$)	1·55
Phosphate of lime ($Ca_3 2PO_4$)	39·52
Phosphates of iron and alumina...	6·50
Residue...	12·00
	99·81

The interstitial cement is of a very soft nature and readily disintegrates. The nodules and fossils therefore drop out in considerable quantities along the bases of the valley escarpments, and, becoming incorporated with the soil, they render it highly fertile and productive. Many of the fossils are of a jet-black colour, due to the substitution of the pre-existing phosphate of lime for phosphate of iron by the decomposition of bicarbonate of iron.[1] *Pecten denudatus*, *P. Pandora*, and *P. varians* occur; *Scalaria retusa* is common; but *S. Ducei* is rare. Among the echinoderms *Brissopis crescenticus*, *Schizaster Parkinsoni*, and *Brissus latus* are common. Pteropods and large-sized Foraminifera, chiefly *Cristellaria* and *Nodosaria*, are enormously prevalent, as well as the teeth of Telostean and other fish, and the rib-bones and vertebræ of Cetaceans.

Division E.—This bed is fully developed in nearly every portion of the two islands, and it is, therefore, the most conspicuous stratigraphical member of the series. In colour it varies from blue to a pale ashen-gray, and it has an average thickness of about 40 feet. It is traversed at different levels by two thin seams of phosphatic nodules; but though of frequent occurrence they are only locally developed. They commence and break off very abruptly. At Maddalena, near the northern extremity of the Great Fault, three of these seams are shown, the uppermost of which is very pockety and disappears in an easterly direction, while to the westward it thins out and breaks off abruptly. The remaining two may be traced for 50 yards to the east, when they, too, break off abruptly. Thin mounted sections of the rock show them to be made up almost entirely of the tests of minute foraminifera, among which *Globigerinæ* predominate. The corals and the *Scalariæ* now become very rare; and pelagic mollusca and other forms characteristic of deep waters take their place. *Terebratula sinuosa*, *Balantium*, and *Vaginella depressa* occur at this horizon. I obtained two specimens of *Aturia aturii* (British Museum Collection) from the middle of

[1] Bicarbonate of iron would be formed by the reaction of iron-oxide, and carbonic-oxide derived from decaying organic matter.

this bed; but below this, *Aturia* does not seem to occur, its place being taken by a large nautiliform cephalopod, many casts of which may be seen in the Valetta Museum.

Division F.—The rock of this division is a yellowish, soft-textured limestone, homogeneous and fine-grained, and composed for the most part of minute, thin-shelled tests of foraminifera. The formation extends throughout the islands, but it varies in thickness from 50 feet in the western parts of Gozo to 30 feet in eastern Malta. A characteristic feature of the bed is the quantity of siliceous concretions which occur in the lower parts of the formation. These concretions have already been described.[1] The upper portion of this bed is not prolific in fossils, but in the lower part, and especially in and around the pockets of phosphatic nodules, numbers are to be found in a good state of preservation. The mollusca are numerously represented: *Pecten denudatus, P. spinulosus, P. cristatus, Conus dubius, C. Russigeri,* and casts of *Arca* are very common. Of the corals, the eight species that occur in the overlying beds are also found here.

The remains of cetaceans and sharks are common, and it was from this horizon that the teeth and vertebræ of *Phoca rugosidens*[2] were obtained. It is noteworthy that no *Scalariæ* have been found below this bed. *Cirsotrema retusa, C. Ducei,* and *C. pumiceum* were found above the third nodule seam, but they were rare. Another interesting fossil which seems to make its first appearance here is the pteropod *Cavolina Cookei*, Simonelli.[3] Its vertical range is very limited, as it appears to be strictly confined to this horizon. The pockety phosphatic seams at Kala and Xeuchia in Gozo yield it in comparative abundance. During the construction of the new dock at Burmola, numerous ribs, vertebræ, and teeth of reptiles having crocodilian affinities were discovered in this bed. A portion of a skull of *Tomistoma champsoides* with teeth *in sitû* and with two vertebræ imbedded by the side of it were obtained from the lower portion of the bed by the Dock engineer, and were presented by him to the Valetta University. Several large pieces of amber, of a dirty brown colour and semi-opaque, were found imbedded in the rock at the same place.

Division G: the third nodule seam.—This layer of phosphatic nodules forms a well-marked horizon in the strata of Malta and Gozo. The nodules are small, and they have a greenish lustre due to the presence of glauconite and phosphate of iron. In chemical composition they vary considerably, those portions of the seam being the richest in phosphoric acid which are the more compact and fossiliferous. The following analysis made by Mr. J. P. Walton, A.R.S.M., represents the average composition of the bed:—

[1] Cooke, J. H., "On the Flint and Chert of the Globigerina Limestones of the Maltese Islands": Geol. Mag., Dec. III, Vol. X, 1893, p. 157.

[2] *Ibid.*, "On the occurrence of *Phoca rugosidens*, Owen, in Maltese Strata": Geol. Mag., Dec. IV, Vol. II, May, 1895, p. 215.

[3] Simonelli, V., "Sopra un nuovo pteropod del miocene di Malta": Bol. del. R. Com. Geol. d'Italia, June, 1894.

Carbonate of lime	51·70
Phosphate of lime	41·46
Peroxide of iron	1·82
Insoluble siliceous matter	3·55
Moisture, etc.	1·47
	100·00

This seam is specially interesting, as it seems to mark the line of demarcation between the Langhian and the Aquitanian series. It is not so fossiliferous as the other phosphate seams. *Pecten denudatus* and *Aturia aturii*, which are so characteristic of and prevalent in the overlying beds, are neither found here nor in any of the strata beneath. Teeth and bones of *Phoca rugosidens*, Owen, were obtained from this horizon in the neighbourhood of Marsa Forno, Gozo. *Pentacrinus Gastaldi, Scalpellum Melitensis, Trochocyathus latero-cristatus, T. pyramidatus, T. vericostatus*, several species of *Flabellum*, and *Stephanocyathus*,[1] are very abundant.

Division H.—This bed of limestone constitutes a considerable bulk of the series that represent the Maltese Aquitanian. It varies from 50 to 80 feet in thickness, and it crops out in every valley and cliff in the two islands. The general character of the bed is that of a yellowish-grey limestone. Sections of the rock under the microscope show it to be made up almost entirely of the calcareous skeletons of foraminifera, among which those of the Globigerinæ, Textulariæ, Uvigerinæ, and Orbulinæ are the most numerous. Minute grains of glauconite, granules of oxide of iron, and curiously-formed nodular masses of manganese having radiating arms of the same mineral, are also abundant.

Coccoliths and rhabdoliths are also present, and like those contained in the *Pietra Leccese* and in the Sicilian rocks (Ragusa) they are of forms similar to those that have been collected in the Adriatic in depths of from 500 to 700 fathoms and described by Schmidt.[2] This limestone is remarkable for the change in the fauna which manifests itself. *Scutella striatula, Thecidium Adamsi, Heterostegina Stricklandi, Cidaris Scillæ*, and *Echinolampas posterolatus*, occur sparingly; but they have not been found in any of the overlying beds. Towards the base of this bed, as well as in phosphate seam iv and in the transition bed at Ricasoli, they are very abundant. A considerable number of fish-remains have been obtained from this horizon in the quarries at Luca. During the governorship of Sir William Reid many of them were figured; but the illustrations were not sufficiently accurate to render them of much scientific value. These illustrations, as well as the original fossils, are now in the Valetta Museum, but the latter are in a very indifferent condition. Spratt[3] has recorded the occurrence in this bed of a fossil turtle; and at St. Julians and Dingli the teeth and

[1] I am indebted to Professor Angelli, of Rome, for the determination of the corals.

[2] Capellini, G., "Della Pietra Leccese e di Alcuni suoi Fossili," Bologna.

[3] Spratt, T., "On the Geology of Malta," Valetta, 1854.

vertebræ of *Stereodon Melitensis*, a fish having sauroid dentition, were found.[1] Leith Adams obtained ear-bones, caudal vertebræ, and a penultimate molar of *Halitherium*[2]; and in the Valetta Museum are several large vertebræ of *Zeuglodon* that, judging from the limestone matrix on them, were also obtained from this bed.

Division I: the fourth nodule seam.—The fourth or lowest seam of phosphatic nodules averages three feet in thickness, and ranges from two to four feet. The nodules are irregular in shape, and generally present an exceedingly wrinkled and coriaceous appearance. Nearly all of them contain one or more fossil organisms, around which the phosphate of lime has segregated; and in many cases they consist almost entirely of the shells of foraminifera. Phosphatized remains of molluscs, corals, and echinoderms, the teeth and vertebræ of sharks, bones of whales, and immense quantities of casts and pseudomorphed tests of pteropods, *Vaginella* and *Hyalea*, enter largely into the composition of the seam. Alluding to the origin of these nodules, Dr. John Murray[3] points out that they are precisely similar to the phosphatic nodules that were dredged from modern sea-beds during the voyage of the "Challenger," and he is of opinion that these nodules, like their modern prototypes, were formed *in sitû* at the bottom of the Oligocene sea. A sample of rock from this seam was sent to Professor J. F. Blake for analysis and report. The following was the result :—

Sulphate of lime	1·97
Carbonate of lime	51·12
Phosphate of lime	31·66
Alumina	10·55
Silica	3·83
Moisture	·87
	100·00

Conclusion.—The foregoing details afford evidences as to the nature of the bathymetric conditions that prevailed when these strata were deposited. These conditions have already been indicated by Dr. John Murray[4] and Dr. J. W. Gregory,[5] and I shall therefore now confine myself to a brief summary of the conclusions which the details in this paper seem to corroborate.

The Globigerina Limestones of the Maltese Islands are broadly divisible into three sections—

I. The lowest beds, comprising the subdivision *I* and the lower

[1] Cooke, J. H., "Notes on *Stereodon Melitensis*, Owen": Geol. Mag., Dec. III, Vol. VIII, December, 1891, p. 546.

[2] Adams, A. L., "On the Discovery of the Remains of *Halitherium*": Q.J.G.S., vol. xxii, p. 595.

[3] Murray, Dr. J., "The Maltese Islands, with special reference to their Geological Structure": Scot. Geog. Mag., vol. vi, p. 449.

[4] *Vide ante.*

[5] Gregory, J. W., "The Maltese Echinoidea, etc.": Trans. Roy. Soc. Edin., vol. xxxvi, p. 585.

portion of *H*, have a composition of from 70 to 90 per cent. of calcium carbonate, and are made up for the most part of shallow-water organisms. These limestones, together with the underlying transition bed and the upper portion of the Lower Coralline Limestone, were laid down on a sinking sea-floor and in about 300 fathoms of water.

II. The subdivisions *D*, *E*, *F*, *G*, and the upper portion of *H*, are composed of from 80 to 90 per cent. of calcium carbonate, the greater portion of which consists of Globigerina and other pelagic organisms. These were probably deposited in about 1000 fathoms.

III. The subdivisions *A*, *B*, and *C* contain from 50 to 70 per cent. of lime. These, together with the overlying "Marls," are considered by Dr. John Murray to have been laid down on a rising sea-floor and to have been within the influence of river waters and their detrital products. They were probably laid down in about 300 fathoms.

The following is a list of the fossils of the formation, about one-half of which are new to the palæontology of the Maltese Miocene, and many are new to science.

Palæontology.—The figures 1, 2, 3 placed after the names of the fossils indicate the occurrence of the fossils in the three sections referred to in the conclusion.

MAMMALIA:

Carnivora—	*Sirenia*[1]—	*Cetacea*—
Phoca rugosidens, Owen, 1, 2.	? Halicore, 1, 3.	Zeuglodon, 3.
P. Scillæ, Capellini, 1.	Halitherium, 1, 2, 3.	Delphinus, 1, 2, 3.
	? Manatus, 1, 2, 3.	Cetacea (gen. ?), 1, 2, 3.

REPTILIA—

? Ichthyosaurus gaudensis, Hulke, 3.	Crocodilus gaudensis, Hulke, 1, 3.
Tomistoma champsoides, Lyd., 1, 3.	Tryonx Melitensis, Lyd., 3.

PISCES—

Stereodon Melitensis, Owen, 1, 2.	Sphærodus, 3.
Notidanus primigenius, L. Ag., 1, 2, 3.	Sphenodus, 3.
Platax Woodwardi, L. Ag., 1.	Hemipristis serra, L. Ag., 1, 2, 3.
Oxyrhina xiphodon, L. Ag., 1, 2, 3.	H. paucidens, P. Gerv., 2, 3.
O. hastilis, L. Ag., 1, 2, 3.	Lamnidæ, 1, 2, 3.
Carcharodon megalodon, L. Ag., 1, 2, 3.	Diodon Scillæ, L. Ag., 2.
Carcharias, 1, 2, 3.	Ætobates, 3.
Holocentrum Melitense, A. S. Woodw.	Chrysophrys, 1, 2, 3.
Odontaspis Hopei, L. Ag., 1, 2, 3.	Scyliidæ, 1, 2, 3.

MOLLUSCA: (1) *Cephalopoda*—Aturia aturii, Basterot, 3. Nautilus, sp. ? 2, 3.

(2) *Pteropoda*—

Vaginella depressa, Daudin, 1, 2, 3.	Hyalea taurinensis, Sism., 1.
Cavolina Cookei, Simonelli, 2.	H., sp., 1, 2, 3.

(3) *Gasteropoda*—

Conus Melitensis, De Greg., 2, 3.	Conus Russigeri, Haues, 1, 2, 3.
C. Mercati, Brocchi, 2, 3.	C. betulinoides, Lamarck, 1, 2, 3.
C. dubius, Gulia, 1, 3.	C. (casts indet.), 3.
C. Melitosiculus, De Greg., 3.	Dolichotoma cataphracta, Brocc., 3.
C. Ruschi, Michelotti, 1, 2, 3.	D. ramosa, Brocc., 3.

[1] Most probably all the Sirenian remains found in Malta are referable to the genus *Halitherium*.—EDIT. GEOL. MAG.

Cirsotrema Swanni, Adams, 3.
C. scaberrima, Mich., 2, 3.
C. Melitensis, Fuchs, 3.
C. Ducei, Wright, 1, 3.
C. crassicostatum, Deshayes, 2.
—— *var.*, 3.
C. retusa, 2, 3.
C. pumiceum, Brocc., 2.
C. taurovaricosum, Sacco, 2.
Cirsotrema (sp. indet.), 3.
Cypræa amygdalum, Brocc., 1.
C. tabagina, Lam., 2, 3.
Turritella inequiculpta, Seg., 3.
T., sp., 2, 3.
Natica pratensis, Raqa., 2.
N. hortensis, Bayan, 1.
Oliva (casts), 1, 2, 3.
Trochus patulus, Brocc., 1.
T. (casts), 1, 2, 3.
Voluta ficularia, Lam., 2.
Cassidaria fasciata, Borson, 3.
C. echinophora, Lam., 3.
—— *var.*, 3.
Cassis Neumayri, Hörnes, 2.
Patella Melitensis, De Greg., 3.
Fissurella, sp., 3.
Erato lævis, Don, 3.
Actæon pinguis, d'Orb., 3.
Solarium simplex, Brong., 2, 3.
Chenopus pes-pelicani, Phil., 3.
Acera (casts), 1, 2, 3.
Xenophora incertissima, De Greg., 3.

(4) *Lamellibranchiata*—

Pecten Melitensis, De Greg., 3.
P. Cookei, De Greg., 2, 3.
P. scabrellus (Lam.), Desh., 3.
—— *var.* arcæopsis, De Greg., 3.
—— *var.* gibbosulus, De Greg., 3.
—— *var.* parti-imbricatus, De Greg., 3.
—— *var.* post-scabriusculus, De Greg., 3.
P., sp. (?), De Greg., 3.
P. Haveri, Mich., *var.* Koheni, Fuchs, 3.
P. denudatus, Reuss, 2, 3.
P. Pandora, 3.
P. Reussi, Hörnes, 3.
P. varians, 3
P. dubius, Wood, 3.
P. spinulosus, 2.
Pecten cristatus, 2.
P. Koheni, Fuchs, 3.
Ostrea cochleare, Poli, 3.
O. mutabilis, Desh., 3.
O. tenuiplicata, Seg., 2.
O. teriodentata, De Greg., 3.
O. perminuta, De Greg., 3.
Lucina sinuosa, Don, 3.
Cardita tornanæta, Bast., 3.
Pholas (casts), 1, 3.
Nuculana pellucidiformis, Hörnes, 3.
N. nitida, Brocc., 2.
N. fragilis, Chemn., 3.
Nucula Mayeri, Hörnes, 3.
Lima, sp., 2, 3.
Arca (casts), 1, 2, 3.
Isocardia (casts), 1, 2, 3.
Astarte (casts), 1, 3.

Brachiopoda—

Terebratula caput-serpentis, 1, 2.
T. Cortæ, Seguenza, 3.
—— *var.* parumlobata, De Greg., 3.
Terebratula minor, 1, 2.
T. sinuosa, 3.
Thecidium Adamsi, McDonald, 1.

Bryozoa—Idmonea, 3.

Crustacea: *Decapoda*—Cancer macrocheilus, Mantell, 3. Cancer, sp., 1, 3.

Cirripedia—

Scalpellum venustum, De Greg., 1.
S. Melitense, De Greg., 1, 2, 3.
S. magnum, Darw., *var.* angustum, De Greg., 1.
—— *var.* equisignatum, De Greg., 1.
—— *var.* radiatum, De Greg., 1.
Scalpellum magnum, Darw., *var.* ornatum, De Greg., 1.
S., sp., 1.
S., sp., 1.
Cirripede, nov. sp.

Echinoidea—

Cidaris Scillæ, Wright, 1.
C. avenionensis, Desml., 3.
Echinus Hungaricus, Laube.
Echinocyamus Studeri, Sism., 2, 3.
Breynella Vassalli, Wright, 3.
Studeria Spratti, Wright, 3.
Echinolampas Manzoni, Greg., 2, 3.
E. posterolatus, Greg., 1.

Hemiaster Cotteaui, Wright, 3.
H. Scillæ, Wr., 1, 2, 3.
H. vadosus, Greg., 1, 2, 3.
Pericosmus latus, Agassiz, 2.
P. coranguinum, Greg., 3.
Schizaster Parkinsoni, Defr., 1, 2, 3.
S. Desori, Wr., 2, 3.
Metalia Melitensis, Greg., 2.
Brissopis crescenticus, Wr., 3.
Spatangus pustulosus, Wr., 3.
Euspatangus De Koninckı, Wr., 3.
Sarsella Duncani, Greg., 2, 3.
S. anterolata, Greg., 2, 3.
Pygorhynchus Spratti, Wr., 2.
Scutella striatula, Greg., 1.
Brissus latus, 3.

Crinoidea—Pentacrinus Gastaldi, Mich., 1, 2.

Alcyonaria: *Gorgonidæ*—

Isis Peloritana, Seg., 1, 3.
I. compressa, Seg., 3.
Isis Melitensis, Seg., 3.
—— *var.* antiqua, Seg., 3.

Actinozoa—

Ceratrochus typus, Seg., 2, 3.
Cœnocyathus Adamsi, Duncan, 3.
Stephanocyathus, sp., 1, 2, 3.
Caryophyllia, 1, 3.
Trochocyathus latero-cristatus, Edw. & H., 1, 2, 3.
T. pyramidatus, Mich., 1, 3.
Trochocyathus vericostatus, Mich., 1,3.
T., sp., 3.
Flabellum extensum, Mich., 1, 2, 3.
F. Melitensis, De Greg., 1.
F. avicula, Mich., 1, 2, 3.
F. intermedium, Mich., 1, 3.
F. fæcundum, Mich., 1, 3.

Spongida—Cliona (perforating shells of Lamellibranchs).

Foraminifera—In addition to the 54 species recorded by Dr. John Murray, I have collected—

Nodosaria soluta, Reuss, 2, 3.
N. consobrina, d'Orb., 3.
Textularia carinata, d'Orb., 3.
Cristellaria cassis, F. & M., 3.
C. radiata, Born., 2, 3.
Cristellaria variabilis, Reuss, 3.
Marginulina Bœhmi, Reuss, 1, 2.
Frondicularia interrupta, Karrer, 3.
Miliolina agglutinans, d'Orb., 3.
Heterostegina Stricklandi, Adams, 1.

NOTICES OF MEMOIRS.

British Association for the Advancement of Science. Sixty-sixth Annual Meeting, held at Liverpool, September 16–28, 1896.

I.—List of Papers read in Section (C), Geology.

J. E. Marr, Esq., M.A., F.R.S., Sec. Geol. Soc., President.

President's Address (see October Number, p. 464).

Prof. W. Boyd-Dawkins.—On the Geology of the Isle of Man.

H. C. Beasley.—Observations on some Footprints from the Trias in the Neighbourhood of Liverpool.

G. H. Morton—Recent Borings in the Red Marl near Liverpool (see p. 496).

G. H. Morton—Erosion of the Sea-coast of Wirral (see p. 516).

T. Mellard Reade—Oscillations in the Level of the Land as shown by the Buried River-Valleys and Later Deposits in the Neighbourhood of Liverpool (see p. 488).

A. Bell.—Tertiary Deposits in North Manxland.

E. Greenly—On the occurrence of Sillimanite Gneisses in Central Anglesey (see p. 494).

E. Greenly—On the Quartzite Lenticles in the Schists of S.E. Anglesey.

Sir W. Dawson.—Pre-Cambrian Fossils—especially in Canada (see p. 513).

G. F. Matthew—Some Features of the early Cambrian Faunas.

Report of the Committee on Zones in British Carboniferous Rocks.

G. H. Morton.—The Range of Species in the Carboniferous Limestone of North Wales.

J. L. Lobley—On the Source of Lava.

J. L. Lobley.—On the Post-Cambrian Shrinkage of the Globe.

P. F. Kendall.—Cause of the Bathymetric Limit of Pteropod Ooze.

P. F. Kendall.—On the Conditions under which the Upper Chalk was deposited.

J. Johnston-Lavis.—The Highwood Mountains of Montana and Magmatic Differentiation. A Criticism.

G. B. Wethered.—The Depths of the Sea in Past Epochs.

Vaughan Cornish.—Rippling of Sand by Water and Wind (see p. 521).

Prof. J. Walther.—Are there Fossil Deserts?

W. W. Watts.—Notes on the Geology of Charnwood Forest (see p. 485).

F. T. Howard and *E. W. Small.*—The Geology of Skomer Island.

H. B. Woodward.—Notes on Sections along the London Extension of the Manchester, Sheffield, and Lincoln Railway between Rugby and Aylesbury.

Report of the Committee on Stonesfield Slate (see p. 517).

Report of the Committee on Coral-Reef Structure.

Report of the Geological Photographic Committee.

Report of the Hoxne Excavation Committee.

John Smith.—On the Discovery of Marine Shells in the Drift Series at High Levels in Ayrshire.

Dr. C. Callaway.—Notes on the Superficial Deposits of North Shropshire (see p. 482).

J. Lomas and *P. F. Kendall.*—Glacial Phenomena of Vale of Clwyd.

P. F. Kendall.—Post-Pliocene Changes of Physical Geography.

Report of the Erratic Blocks Committee.

Prof. E. Hull.—Another Possible Cause of the Glacial Epoch (see p. 514).

Report of the Committee on the High-level Shell-bearing Deposits at Clava.

Report of the Singapore Caves Committee.

Report of the Calf-Hole Cave Committee.

Report of the Committee on the High-level Flint Drift at Ightham.

Report of the *Cetiosaurus* Committee.

Report of the Eurypterid Committee.

Report of the Committee on the Fossil Phyllopoda.

Report of the Committee on Life-zones in Carboniferous Rocks (see p. 519).

A. C. Seward—A New Cycad, from Portland (see p. 518).

A. C. Seward—A Large Specimen of *Lyginodendron* (see p. 518).

Report of the Committee on the Registration of Type Specimens.

Montagu Browne.—The Rhætic Bone-beds of Aust Cliff and the Rock-bed above it.

Prof. H. G. Seeley.—On the Skull of the South African Fossil Reptile *Diademodon.*

Prof. H. G. Seeley.—Two examples of Current Bedding in Clay.

Sir Archibald Geikie.—On some Crush-Conglomerates in Anglesey (see p. 481).

Prof. J. Milne.—Report of the Seismological Committee.

A. C. Seward.—Note on some Fossil Plants from South Africa (see p. 519).

Prof. K. Busz.—On the occurrence of Corundum produced by Contact-metamorphism (see p. 492).

Report of the Moreseat Committee.

ABSTRACTS OF PAPERS READ AT THE BRITISH ASSOCIATION MEETING, LIVERPOOL, SEPTEMBER, 1896.

II.—PRE-CAMBRIAN FOSSILS. By Sir W. DAWSON, LL.D., F.R.S.

THE author stated that it was his object merely to introduce the specimens he proposed to exhibit by a few remarks rendered necessary by the present confusion in the classification of pre-Cambrian rocks. He would take those of Canada and Newfoundland as at present best known, and locally connected with the specimens in question.

He referred first to the "*Olenellus* Zone," and its equivalent in New Brunswick, the "*Protolenus* Fauna" of Matthew, as at present constituting the base of the Cambrian, and terminating downward in barren sandstone. This Lower Cambrian had in North America, according to Walcott, afforded 165 species, including all the leading types of the marine invertebrates.

Below the *Olenellus* Zone, Matthew had found in New Brunswick a thick series of red and greenish slates, with conglomerate at the base. It has afforded no Trilobites, but contains a few fossils referable with some doubt to Worms, Mollusks, Ostracods, Brachiopods, Cytideans, and Protozoa. It is regarded as equivalent to the Signal Hill and Random Sound Series of Murray and Howley in Newfoundland, and to the Keweenian, and the Chuar and Colorado Cañon Series of Walcott in the west. The latter contains laminated forms apparently similar to Cryptozoon of the Cambrian and Archæozoon of the Upper Laurentian.

The Etcheminian rests unconformably on the Huronian, a system for the most part of coarse clastic rocks with some igneous beds, but including slates, iron-ores, and limestones, which contain worm-burrows, sponge-spicules, and laminated forms comparable with Cryptozoon and Eozoon. The Huronian, first defined by Logan and Murray in the Georgian Bay of Lake Huron, has been recognized in many localities, both in the west and east of Canada and the United States; but designated by other local names, and by some writers is included, with the Etcheminian and sometimes with

part of the Laurentian, in the scarcely-defined "Algonkian" group of the United States Geological Survey.

Below the Huronian is the Upper Laurentian or Grenville system, consisting of gneisses and schists (some of which, as Adams has shown, have the chemical composition of Palæozoic slates), along with iron-ore, graphite, and apatite, and great bands of limestone, the whole evidently representing a long period of marine deposition, in an ocean whose bed was broken up and in part elevated before the production of the littoral clastics of the Huronian age. It is in one of the limestones of this system that, along with other possible fossils, the forms known as *Eozoon Canadense* have been found. The author did not propose to describe these remains, but merely to exhibit some microphotographs and slices illustrating their structure, referring to previous publications for details as to their characters and mode of occurrence.

Below the Grenvillian is the great thickness of orthoclase gneiss of various textures, and alternating with bands of hornblende schist, constituting the Ottawa gneiss or Lower Laurentian of the Geological Survey. No limestones or indications of fossil remains have yet been found in this fundamental gneiss, which may be a truly primitive rock produced by aqueo-igneous or "crenitic" action, before the commencement of regular sedimentation.

The author proposed, with Matthew, to regard the Etcheminian series and its equivalents as pre-Cambrian, but still Palæozoic; and, as suggested by himself many years ago, to classify the Huronian and Grenvillian as *Eozoic*, leaving the term Archæan to be applied to the Lower Laurentian gneiss, until it also shall have afforded some indications of the presence of life.

He insisted on the duty of palæontologists to give more attention to the pre-Cambrian rocks, in the hope of discovering connecting links with the Cambrian, and of finding the oceanic members of the Huronian, and less metamorphosed equivalents of the Upper Laurentian, and so of reaching backward to the actual beginning of life on our planet, should this prove to be attainable.

III.—Another Possible Cause of the Glacial Epoch. By Professor Edward Hull, LL.D., F.R.S., F.G.S.

THE author gave an account of the results arrived at by Professor J. W. Spencer, Ph.D., in his memoir on "The Reconstruction of the Antillæan Continent" (Bull. Geol. Soc. America, January, 1895), from observations laid down on the Admiralty charts of the east coast of North America and the shores of the West Indian Islands and Gulf of Mexico. He shows that the "continental shelf" lying between the coast and the 100-fathom line is succeeded by a second and deeper plateau, called by Professor A. Agassiz "the Blake plateau," the average depth of which may be taken at 2,700 feet, separated from the continental shelf by a steep descent, and in its turn bounded by a second steep descent leading down to the abysmal depths of the Atlantic Ocean at 12,000 or 13,000 feet

below the surface. A careful investigation of the soundings shows that these plateaux are traversed by channels, sometimes of great depth and with precipitous sides, leading down from the *embouchures* of the existing rivers which open out on the coast, and connected with the outer margins of the plateaux by wide embayments. The form of these channels would in some cases entitle them to be called "cañons" or "fjords"; and as Professor Spencer truly considers that such channels could only be formed by river erosion, he concludes that the whole eastern coast and the West Indian Isles were elevated to the extent of the outer embayments where they open out on the floor of the ocean. Such an elevation of 12,000 feet or so would have connected North and South America along the line of the Antilles, constituting a single continent, and are termed "stupendous changes of level" of the Pleistocene epoch.[1]

The author of this paper proceeds to discuss some of the climatic conditions which would result from such changes, and supposes that the elevation of the Antillæan continent would have shut out the northern branch of the great equatorial current, known as the Gulf Stream, from the Caribbean Sea and the Gulf of Mexico, causing it to enter the North Atlantic directly; and he comes to the conclusion that the Atlantic current would have crossed the 40th parallel with a surface temperature of only 74° F. instead of 84° F., as is the case at the present day. The author then discusses the question to what extent such a lowering of the temperature of the present Gulf Stream would have affected the climate of the regions bordering the North Atlantic, and considers that this effect may be approximately arrived at by transferring the climatic conditions of the isotherm of annual mean temperature of 32° F. (the freezing-point of water) to those of the 42° F. of the present day, resulting in subglacial conditions along the line of this isotherm.[2]

Proceeding next to examine the effects of the elevation of the American continent to the extent required by Professor Spencer's conclusions, the author considers it as extremely probable that the cold produced by this physical change, added to that due to the lowering of the temperature of the Atlantic current, would result in bringing about the conditions of the Glacial epoch; and as similar elevation of land has been determined in the case of the platform of the British Isles and North-Western Europe—though to a much smaller extent than in the case of the American continent—the increased cold due to this cause, added to that due to the diminished temperature of the Atlantic current, would have been, if not a *vera causa* of the Glacial epoch of Europe, a most material cause in bringing about the climatic conditions of that epoch.

[1] For those who are unable to obtain Professor Spencer's original memoir, the review thereof by Mr. A. J. Jukes-Browne, F.G.S., in the GEOLOGICAL MAGAZINE for April, 1895 (p. 173), will probably suffice.

[2] The isotherm of 42° passes by the north coast of the British Isles.

IV.—Erosion of the Sea-coast of Wirral. By G. H. Morton, F.G.S.

THE oldest maps of the coast of Wirral, the north-western extremity of Cheshire, afford very little information on the exact outline of the coast in former years. It was not until the publication of the 6-inch map of the Ordnance Survey in 1880, that it became possible to make exact observations on the erosion of the coast. The late Sir James Picton, F.S.A., in 1846, was the first to direct attention to the waste of the land, but he had not made any personal investigation, and more recent writers on the subject have confined themselves to showing the incorrectness of some of his statements, rather than making original observations. The object of this paper is to record the result of close attention given to the subject for many years.

Half a mile south-west of the Leasowe Embankment, and about 100 yards from Seabank Cottages, there is an old weather-beaten brick and stone house, known as the "Warren," and evidently the oldest in the neighbourhood. According to the 6-inch Ordnance Map, the distance between the house and the sea was about 130 yards when the country was surveyed in 1871, but I found it to be 70 yards in 1890, 55 yards in March 1894, and only 45 yards in May 1896, and the residents have shown me the position of several high sand-hills that once formed part of the lost land.

In an affidavit, filed in a recent case concerning the extension of the Embankment, George Banks states that he had been born and had lived in the house ever since. It was only 60 yards from high-water mark at spring tides in 1892, "whereas when he first remembered it, the house stood at least 350 yards from high-water mark at spring tides, and the land washed away included some sand-hills 30 and 40 feet, and one 50 or 60 feet in height."

The greatest erosion by the sea along the coast has taken place at Dove Point, about 350 yards to the south-west of the house. In 1862 there were two "perches" constructed of timber, one being 10 yards from the edge of the sand-hills, which were then about 12 feet high, and the other 150 yards behind, near the boundary of the enclosed land. The seaward perch is shown in the frontispiece of the "Geology around Liverpool." On January 20, 1863, this perch had become close to the edge of the cliff and fell down on the shore, its original position being indicated by several masses of masonry and large stones which had formed the foundation of the structure. The perch was re-erected on the sand-hills, and is shown on the 6-inch map, but it was afterwards removed, with the one behind, to the north-east of the "Warren," so that neither of them is now in the place shown on the map. The foundation stones still lie on the shore in their original position. In consequence of the continual erosion by the sea the stones have gradually become further from the coast-line, and in September, 1894, the distance was 144 yards, showing the erosion of the coast from 1863 to 1894 to have been between 4 and 5 yards per annum. In May, 1896, the

distance had been increased to 152 yards, proving an erosion of 8 yards in 20 months, but as they included two winters the loss would be about 4 yards per annum.

South of Dove Point the erosion gradually decreases, but 50 yards of the sand-hills have been washed away on the north-east of Sandhey, though not in recent years, as there is now a fringe of grass growing in the denuded bay for about 100 yards, when it gradually dies away. The grounds along the sea-front at Sandhey are protected by an embankment and groins, which arrest the encroachment of the sea. Beyond, in front of Hoylake, there is no erosion, and the Red Stones at Hilbre Point protect the land from the sea.

V.—Stonesfield Slate.—Third and Final Report of the Committee, consisting of H. B. Woodward (Chairman), E. A. Walford, F.G.S. (Secretary), Professor A. H. Green, Dr. H. Woodward, and J. Windoes, appointed to open further sections in the neighbourhood of Stonesfield in order to show the relationship of the Stonesfield Slate to the underlying and overlying strata. (Drawn up by Edwin A. Walford, F.G.S., Secretary.)

THE succession from the Great Oolite through the Stonesfield Slate into the Inferior Oolite, as shown in the sections made by your Committee, may be thus summarized :—

		Ft.	in.
Great Oolite	Limestone with corals		
	Limestone and marls with *Ostrea* (oyster beds) ...	17	3
	Slate beds (Stonesfield Slate)	5	3
Fullonian	Fawn-coloured limestone with lignite and carbonaceous markings (Chipping Norton Limestone) .. .. about	18	0
Inferior Oolite Series	Sandy limestones with some marl beds; lower limestone with vertical plant-markings (Lower Estuarine Series)	11	0
	Clypeus-grit: zone of *Ammonites Parkinsoni* ...	13	0

(About 12 feet of Inferior Oolite strata can be made out below.)

The faulted state of the bank prevents exact measurement of the series now assumed to be Fullonian. These beds had previously been classed with the Inferior Oolite. Notwithstanding the great care taken in making a practically vertical section, a series of Great Oolite beds was found at a much lower level than the Slate. The error was indicated in the Second Report, and the greater part of beds Nos. 18 to 26 has to be excised from the list.

The additions to our knowledge consist mainly in the discovery of the strata with vertical plant-markings (evidently the equivalent of the Lower Estuarine Series of the Northamptonshire Inferior Oolite), and in the particulars given of the thickness of the higher beds of the Inferior Oolite and the Fullonian strata. Fawler, two miles distant, has been supposed to mark the virtual disappearance of the Inferior Oolite. Sir Joseph Prestwich, however, had grouped with the Inferior Oolite certain beds (14 feet 6 inches thick) which

had been proved in the boring at Wytham, near Oxford;[1] and Mr. H. B. Woodward has classed with the Inferior Oolite Series 30 feet of strata proved in a boring at Witney.[2] These correlations were inferential, but the facts now brought forward give them support.

VI.—A New Cycad from the Isle of Portland. By A. C. Seward, M.A., F.G.S.

DR. WOODWARD lately obtained an exceedingly fine specimen of a cycadean stem from the Purbeck Beds of Portland, which is now in the fossil plant gallery of the British Museum. The stem, which is probably the largest known, has a height of 1 m. 18·5 cm., and measures 1 m. 7 cm. in girth at the broadest part. A striking feature of the specimen is the conical apical bud enclosed by tapered bud-scales, bearing numerous ramental outgrowths on the exposed surface. The surface of the stem presents the appearance of a prominent reticulum of projecting ridges, of which the meshes were originally occupied by the persistent petiole bases. The substance of the leaf-stalks has for the most part disappeared, while the inter-petiolar ramental tissue has been mineralized and so preserved as a projecting framework. In structure the ramenta are practically identical with those of *Bennettites*, as described by Carruthers and other writers. The petiole bases also agree very closely with those of *Bennettites*, consisting of a mass of parenchymatous tissue traversed by numerous vascular bundles and secretory canals, with a distinct band of cork at the periphery. No trace of any inflorescence has been found. It is proposed to name the plant *Cycadeoidea gigantea*.

VII.—Note on a Large Specimen of *Lyginodendron*. By A. C. Seward, M.A., F.G.S.

THE specimens on which this description is based are in the Botanical Department of the British Museum and in the recently acquired Williamson Collection. The block, from which several sections have been prepared, is a striking example of the preservation of the minute structure of a Coal-measure plant on a large scale; it consists of a mass of wood at least 6 cm. thick in a radial direction, and a pith about 3 cm. in diameter, but without any trace of cortical tissue. Sections obtained from this block, and included in the Williamson Collection, were described at some length in the recently published memoir by Williamson and Scott on *Lyginodendron* and *Heterangium*. The examination of additional specimens has led to a somewhat fuller diagnosis of the structure and a more detailed comparison with *Lyginodendron Oldhamium* and other plants. The main mass of the wood possesses a structure practically identical with that of *Lyginodendron Oldhamium* and recent cycadean stems; internal to the centrifugally developed

[1] Geol. Mag. 1876, p. 238.
[2] "Jurassic Rocks of Britain," vol. v, 1895, p. 42.

secondary wood there is a fairly complete and narrow ring of centripetally developed xylem. In the pith there are numerous secretory canals and nests of dark-coloured sclerous cells. No definite traces of primary xylem like that of *Lyginodendron Oldhamium* have been detected. As a matter of convenience the specimen may be designated *Lyginodendron robustum.*

VIII.—Note on some Fossil Plants from South Africa. By A. C. Seward, M.A., F.G.S.

THE author has recently had an opportunity, through the kindness of Mr. David Draper, F.G.S., of examining a collection of fossil plants from a locality a short distance south of Johannesburg. The collection forwarded to England by Mr. Draper includes examples of *Glossopteris, Vertebraria,* and other genera, associated with specimens of *Lepidophloios.* The occurrence of Lepidodendrons in strata containing typical members of the *Glossopteris* flora is extremely important from the point of view of the geological and geographical distribution of fossil plants, and specially interesting in connection with a similar association lately recorded by Professor Zeiller in Brazilian plant-bearing beds. In South Africa, as in South America, we have evidence of the existence of a plant genus characteristic of the Upper Palæozoic flora of the northern hemisphere, in the same region with the Permo-Carboniferous *Glossopteris* flora.

IX.—Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of J. E. Marr, F.R.S. (Chairman), E. J. Garwood, F.G.S. (Secretary), and A. H. Foord, F.G.S., appointed to study the Life-zones in the British Carboniferous Rocks. (Drawn up by J. E. Marr.)

IN a paper read before the British Association at Ipswich in 1895, two of us called attention to the work of Dr. Waagen on the Upper Palæozoic rocks of the Salt Range, and gave reasons for supposing that the Carboniferous rocks of Britain might be divided into zones.[1] In that paper it was suggested "that a committee be appointed to inquire into the possibility of dividing the Carboniferous rocks into zones, to call the attention of local observers to the desirability of collecting fossils with this view, and, if possible, to retain the services of eminent specialists to whom these fossils may be submitted." This committee was appointed, and the members thereof beg leave to submit their report.

The Committee believes that the following districts would furnish good results, and recommends that those whose names are appended to the various districts be asked to take charge of their particular districts and to endeavour to carry out therein the objects of the Committee—

[1] See Rep. Brit. Assoc. 1895, p. 696.

England and Wales: Northumberland and the Border, Professor G. A. Lebour; Northern part of Pennine Chain and adjoining regions, Messrs. Garwood and Marr; Southern part of ditto and adjoining regions, Mr. P. F. Kendall and Dr. Wheelton Hind; North Wales, Mr. G. H. Morton; South Wales, Mr. A. Strahan; Devon, etc., Mr. Howard Fox and Dr. G. J. Hinde.

Isle of Man: Mr. G. W. Lamplugh.

Scotland: Mr. B. N. Peach.

Ireland: Mr. A. H. Foord.

The Committee recommends that the following directions for working be communicated to the various workers:—

1. When possible, a typical measured section should be given of each locality examined, with notes of as many confirmatory sections as possible.

2. Any specimen not actually found *in sitû* to be labelled to that effect, with the exact conditions under which it was found noted.

3. All specimens should be labelled with the local name of the bed, giving as many additional details as possible, and in all cases the exact locality, which should further be noted on a large scale-map.

4. All specimens should be labelled *when found*.

5. So far as possible, workers are recommended to collect from one bed at a time, and to pack the specimens from each bed in a separate parcel before commencing to collect from another bed.

6. Attention should be paid to apparently identical forms separated by many feet or yards of deposit, as the forms may be *mutations*; large suites of such specimens should be collected; indeed—

7. As large a number of specimens as possible should be obtained of each species in every bed examined.

8. Absence of fossils in any bed should be noted whenever possible.

9. Attempts should be made to record the relative abundance of fossils, which may be roughly done by recording those which are very rare (*v. r.*), rare (*r.*), common (*c.*), and very common (*v. c.*).

10. In case of beds being obviously rich in micro-organisms, large pieces should be collected for future examination.

11. Considering the importance which cherts have assumed, it is very desirable to collect specimens of cherts.

Specimens may be kept by the discoverers or forwarded to the Secretary of the Committee (E. J. Garwood, Dryden Chambers, 119, Oxford Street, London, W.), on loan or for retention.

The Committee recommends that the names of those whom they have mentioned as likely to undertake the charge of districts be added to the Committee, and that the following palæontologists be asked to co-operate with the other members, and to identify such fossils as may be submitted to them, their names being also added (when not previously mentioned) to those of the Committee: Dr. G. J. Hinde (radiolaria and sponges), Professor H. A. Nicholson

(corals), Mr. J. W. Kirkby (entomostraca), Dr. H. Woodward (other crustacea), Mr. F. A. Bather (echinoderms and brachiopods), Dr. Wheelton Hind and Mr. E. J. Garwood (lamellibranchs and gasteropods), Messrs. G. C. Crick and A. H. Foord (cephalopods), and Mr. R. Kidston (plants).

The Committee recommends that a grant be applied for, in order to pay for the services of collectors, who are to be under the direction of the Secretary of the Committee.

X.—The Rippling of Sand by Water and by Wind. By Vaughan Cornish.

REGULAR ripple-mark is produced in various ways in *rolling* sand. The billows formed by deposition of flying or floating sand are considered in another paper (Section E—Geography). The author distinguishes three principal kinds of rippled sand, viz.:

1. The Ripple-mark of Sea.
2. The Ripple-mark of Streams.
3. The Ripple-mark of Dunes.

In (1) symmetrical, knife-edged ridges are built up, owing, as is well known, to the complete reversal of the current at short intervals, which results in an effective co-operation of the direct current with the vortex formed in the lee of projections on the rough surface of the sand. This mechanism in the vertical plans raises the ridges, and, in plan, extends them laterally, so that the mottled surface of the initial stage is changed into long lines of parallel ridge and furrow.

If the direction of the waves changes, another set of ridges is formed, and this produces polygonal figures. These have an even number of sides, and the sides are arranged in opposing pairs. This serves to discriminate polygonal forms due to fossil ripple-mark from Hitchcock's supposed fossil tadpole-nests.

2. The symmetrical, rounded, ripple-mark of the sandy bottom of a stream is formed by the alternate acceleration and retardation of current which occurs wherever the surface of the water is corrugated by a train of standing waves. This form has been called Ripple Drift. The ridges only travel when the whole train of water-waves travels; when the train of waves arises from a *fixed* obstacle the sand ridges are stationary.

3. The ripple-mark of dunes is produced when sand-grains roll before the wind. These ripples are not symmetrical, but they preserve their sectional shape during their growth, the height and length increasing in the same proportion. They grow laterally in the same way as (1). They are produced by the steadiest natural wind, and even by a steady artificial blast, the resistance offered by the sand-grains being sufficient to produce in yielding air a periodic motion such as must be independently produced in water for the formation of the ripple-mark of sea or stream.

Flying-sand falling upon the surface of a sand-dune blurs the pattern of the ripples, but if the shower be not too thick the grains are soon sorted into position as they roll.

REVIEWS.

I.—Reminiscences of a Yorkshire Naturalist. By the late William Crawford Williamson, LL.D., F.R.S., Professor of Botany in Owens College, Manchester. Edited by his Wife. 8vo, pp. xii and 228. (London: George Redway, 1896.)

THIS little volume contains a record of the principal events in the life of the author, written by himself, and tenderly edited by Mrs. Williamson after his death.

It falls to the lot of but few amongst us to have the events of our lives set down in a book, and it may very well be doubted if such records, save in a few exceptional instances, are worth the expenditure of ink and paper. Professor Williamson may be looked upon as one of these exceptional instances; indeed, it would be extraordinary if, having attained his 79th year in the present century, and witnessed some of the greatest changes brought about by scientific discovery and invention, he should have failed to record many matters of vital interest to the *fin du siècle* world of which he saw the earlier days.

Born of humble parents, and by nature a delicate boy, young Williamson's early schooldays were interrupted by long enforced holidays spent delightfully upon a farm in Yorkshire. At other times he went birds'-nesting or collecting insects, or he watched an uncle who executed work with a lapidary's wheel, cutting agates and other stones obtained along the coast. Later on he assisted his father in his duties as Curator of the Scarborough Museum, and made the acquaintance of that grand old man William Smith, the "father of English Geology," and also of his nephew, Professor Phillips, whose "Geology of the Yorkshire Coast" was young Williamson's first introduction to a scientific work on the geology of the country around his boyhood's home. At the age of fifteen Williamson was sent to school at Bourbourg, in France; to accomplish which he incurred many trials, and his parents considerable additional expense: when he left he had learned little more of colloquial French than he had brought with him, and gained no compensating advantages. Returning to London in 1832, his father directed him to call upon Sir Roderick Murchison, by whom he was well received, and breakfasted with that great man and Lady Murchison, who was most kind to the country lad.

After "doing the sights of London" he returned home, and was forthwith apprenticed to a general practitioner in Scarborough, and became in process of time what is nowadays termed in joke a "pill-box." He only remained with Mr. Weddell, of Scarborough, three years, when, in September, 1835, he was permitted to resign his articles, and was appointed Curator to the Museum of the Manchester Natural History Society, a post which he held until he was twenty-two years of age.

In 1838 young Williamson earnestly desired to qualify himself as a medical man; but for this purpose his medical studies, so long neglected for Natural History work, must be taken up in earnest.

The question was, how could the necessary funds be raised. He had prepared a series of six lectures on Geology with appropriate diagrams and specimens; with these he visited the chief towns of Lancashire and Yorkshire, and thus earned sufficient to cover his fees at the medical school in Manchester, and to pay for his board and pocket-money. In September, 1840, he set out for London, and entered as a student at University College. In 1841, his examination passed, we find young Williamson a full-fledged practitioner, with a brass-plate on the door of his house, at the corner of Wilton Street and Oxford Road, Manchester.

It was a hard, uphill climb for the young surgeon; indeed, at first it seemed to be a case of "*facilis descensus Averni*"; an old medical friend remarking sagely to the young one: "You will have for some time to go much oftener down steps than up steps. Never mind! win the good opinion of washerwomen and such like, and in time you will hear of their recommendations of you to the wealthier families by whom they are employed." "I followed his advice," says Williamson, "and found it succeeded as predicted."

But one may well ask, where does the title of a "Yorkshire Naturalist" come in? To understand this, it is necessary to read the book. The fact is, he had only been apprenticed to Mr. Weddell in Scarborough two years when he began to publish his observations as a naturalist in the "Magazine of Natural History," the first paper being "On a Rare British Species of *Mytilus*," and the second "On the Distribution of Organic Remains in the Lias Series of Yorkshire," etc. (Proc. Geol. Soc., vol. ii, 1833–8). Then, a "Description of a Tumulus opened at Gristhorpe," 1834, followed by "Illustrations and Descriptions for the Fossil Flora of Great Britain," by Lindley and Hutton, 1835, whom he assisted with notes and drawings. Also on the "Distribution of Organic Remains in the Oolite of Yorkshire," 1836. These papers, commenced at the age of 18, and continued with greater knowledge in later years, only ended in 1895, the year of his death, when they numbered 145, including nineteen important memoirs on the structure of fossil plants read before the Royal Society of London and published in the Philosophical Transactions, 1870–93. The fact of his having held the Chair of Professor of Botany in the Owens College, Manchester, for forty-one years, speaks volumes for his indomitable energy and ability; and when one considers that he carried on an extensive private medical practice in Manchester at the same time, one is the more impressed by his power of work. That he should have found time in the midst of all his other labours to cut, grind down, mount, and prepare a large proportion of the sections of fossil plants from the Coal-measures which he described in his numerous papers, seems almost incredible; but his whole life was occupied with his pursuits, and he had no idle time, and certainly during his long life he never wasted any.

Besides the narrative of actual work performed by Professor Williamson—which, as a public lecturer alone, would have satisfied the craving for occupation of any ordinary strong man!—we have

the sketch of his work in Owens College from 1851 to 1892; his pursuit of medicine as a practitioner in Manchester; his fossil botanical studies, resulting in the fine series of monographs on the microscopic structure of the plants of the Carboniferous period; the outcome of the examination of the hundreds of slides prepared with his own hands; his microscopic investigation of the bones, teeth, and scales of fishes; and on Foraminifera and other lowly organisms: these are only a small part of the records of his busy life. That he should have been elected to the Royal Society in 1854, been a Royal Medallist in 1874, an LL.D. and an honorary member of many learned societies, seems but fitting and just. Of his social and family records much is told in this volume, and we learn of all those with whom Williamson became acquainted in his long life. Some of these notes are of much interest, but others are only valuable to those of his own immediate household. His name will survive for long in scientific circles as a palæobotanist, and his Scarborough and Manchester friends will no doubt keep his memory green. Beneath the surface of this long and busy life, we may read this lesson—that success can only be attained by patient study, diligence, and self-denial; these Williamson practised, and, combined with an ardent love of natural history, made the curious and inquiring child the father of the earnest man of science and the Yorkshire Naturalist.

II.—Dr. G. Agamennone on Earthquakes in the South-East of Europe.

(1) Liste des tremblements de terre qui ont eu lieu dans l'Empire Ottoman pendant l'année 1894.

(2) Bulletin météorologique et séismique de l'Observatoire Impériale de Constantinople. Partie Séismique. I Année (1895).

(3) L'activité sismique en Orient, et en particulier dans l'Empire Ottoman pendant l'année 1895.

(4) Tremblement de terre de Paramythia (Epire) de la nuit du 13–14 mai 1895. (Boll. Soc. Sismol. Ital., i, 1895, pp. 121–130.)

(5) Vitesse de propagation du tremblement de terre de Paramythia (Epire) dans la nuit du 13–14 mai 1895. (Boll. Soc. Sismol. Ital., ii, 1896, pp. 3–14.)

The organization of earthquake-studies in the Balkan peninsula has advanced remarkably during the last few years. The number of self-recording instruments erected is still small, but as in each country the Meteorological Office undertook the seismological work, the existing network of stations was immediately available. In Servia and, strange to say, in Austria-Hungary, no regular provision seems to be made for the collection of earthquake observations; but Dr. Hepites in Roumania, M. Watzoff in Bulgaria, and Dr. Papavasiliou in Greece, are doing very valuable work in this direction.

In Turkey, the foundation of the geodynamic section of the meteorological observatory was due to the interest excited by

the Constantinople earthquakes of July, 1894. The authorities were fortunate enough to secure the services as Director of Dr. G. Agamennone, whose excellent work as assistant in the Meteorological and Geodynamic Office of Rome is widely known among seismologists. The success achieved by him in one year proves that something good can even yet come out of the Ottoman Empire.

The first of the above-mentioned papers is a catalogue of forty-nine shocks felt in Turkey alone in 1894. This includes the Constantinople earthquake and many of its after-shocks. In the following year, Dr. Agamennone commenced the publication of monthly *Bulletins*, and at the same time widened the area of investigation so as to embrace all the countries bordering the eastern end of the Mediterranean. The third paper, published in the *Bulletins* for December, 1895, and January, 1896, contains a summary of the results for 1895. Instead of the 49 shocks chronicled in the previous year, we have no fewer than 400 observed in Turkey, 236 in Greece, 55 in Bulgaria, and 62 in the remainder of the region, making a total of 753, or about two a day. The majority of these are connected with several well-marked earthquake-centres, of which Dr. Agamennone discriminates thirty-one as having been in action in 1895. The Constantinople centre has sunk into relative unimportance, only ten shocks being known to have their origins in the neighbourhood of that city.

One of the most important earthquakes in 1895 was that felt at and near Paramythia during the night of May 13–14. Its intensity was between the degrees ix and x of the Rossi-Forel scale. At least seventy persons were killed, and more than 500 houses were destroyed, within an area of about 150 square miles. The shock was felt at Zante, about 110 miles from the epicentre, and was registered at several observatories in Italy, and also at Nicolaiew, in the south of Russia. From the times obtained at these places and near the epicentre, Dr. Agamennone estimates that the early tremors travelled at about 1·21 miles a second, and the larger pulsations at about 0·88 miles a second. C. Davison.

CORRESPONDENCE.

THE PENEPLAIN OF THE SCOTCH HIGHLANDS.

Sir,—Your Magazine for last March contains an article by Messrs. Macnair and Reid that touches on a chapter in Scotch geology and geography which has interested me for some time past; but, unhappily, the few words of discussion that I contributed to the problem in a footnote to an article on a very different subject[1] seem to have been misunderstood by the above-named authors.

The problems discussed by Messrs. Macnair and Reid include a consideration of the geographical conditions obtaining in Scotland

[1] "The Development of certain English Rivers": London Geogr. Journ. 1895, p. 139.

during Old Red Sandstone time. Among these conditions, the form of the floor of ancient rocks on which the Old Red lies unconformably may be regarded as of prime importance.

The problem to which my attention had been attracted is the date and process of origin of the now uplifted peneplain in which the Scotch glens of to-day are carved. Judging by analogy with other peneplains, that of the Scotch Highlands can hardly have been longer exposed to dissection than since the latter part of Mesozoic time; indeed, Tertiary time alone may have been sufficient for the excavation of the narrow glens in the hard rocks of the Highlands, as well as for the more general denudation of the weaker rocks of the Lowlands. It is, therefore, not unreasonable, in my view of the matter, to regard the broad denudation by which the Highland peneplain itself was formed as having been completed in Cretaceous, or, at earliest, in Jurassic time. Whether this denudation was accomplished by marine or by subaerial agencies, or by the co-operation of both, I see no means of deciding definitely; but, for various general reasons, I incline to ascribe it chiefly to subaerial agencies.

Now, the reason that my brief footnote afforded material for quotation by Messrs. Macnair and Reid is, that I referred therein to the views of Sir A. Geikie concerning the date of the Highland peneplain, from which I took the liberty of dissenting; but I am at a loss to understand why a quotation from my footnote should be cited as "a very good example of the misconception and general indefiniteness which accompany Sir A. Geikie's description." If the brief note be misconceived and generally indefinite, the blame should fall on no one but myself.

In continuation, Messrs. Macnair and Reid seem to infuse their own views into my words when they say—"Professor Davis speaks of Devonian seas having cut down the Highlands to their base-level." On the contrary, I said that "Devonian erosion consumed a great volume of the contorted and overthrust rocks of the Highlands." Whether this erosion was marine or subaerial, is a difficult matter to decide, and I did not undertake to decide it. That the erosion of that time reduced the Highlands to base-level, was regarded as probable, but was not directly asserted.

Moreover, my use of the terms "Devonian" and "Old Red" was as synonyms—not for a moment as names of different times or of successive formations. Furthermore, I said nothing to justify the statement that "Professor Davis speaks . . . as if there were two distinct sets of rocks in Scotland, one marine . . . the other fresh-water." The question of the marine or lacustrine deposition of the Old Red (Devonian) was not raised in my note. On the other hand, I cannot justly take shelter under the statement of Messrs. Macnair and Reid that any error in my note "is quite excusable in one who has never studied the rocks of our country, but only read of them in the 'Scenery of Scotland,'" for my reading extends much further; and while I have not "studied" the rocks on the ground, I have at least seen some of them, and in most enjoyable company, from the Buried pre-Torridonian mountains

on the shore of Loch Maree to the Carboniferous rocks of the Lowlands. But from these personal matters, let me turn again to the problem of the Highland peneplain.

It seems to me beyond dispute that a great denudation (whether marine or subaerial is here irrelevant) preceded the deposition of the Old Red (Devonian), because its lowest strata are strongly unconformable on their foundation. The place where the detritus furnished by this denudation was deposited is unknown; but this does not weaken the evidence of the denudation. The precise date of the denudation is not defined; it certainly preceded the deposition of the Old Red, but its chief accomplishment may have been at a considerably earlier date; indeed, after the greater part of the denudation had been effected, there may have been some deformation; and upon this deformed denuded surface, the Old Red deposition may have been begun. This can only be told by piecing together such fragments of the Old Red floor as are now in sight, restoring them to the position that they had at the beginning of Old Red deposition by allowing for the dip that the Old Red strata have since then gained, and then judging as well as may be whether the restored floor has the form of a surface of denudation or of deformation. Likely enough, this problem is not definitely soluble; but as far as I have read, the facts fully support the general statement that "a vast denudation was accomplished in earlier times than the Old Red Sandstone period." The contention that there was no such vast denudation does not seem to me well grounded. On the other hand, it seems equally indefensible to maintain that the surface produced by the very ancient pre-Old Red denudation is essentially identical with the once continuous peneplain of the Highland ridge-tops. Whatever even floor was produced before the beginning of Old Red deposition, it must be altogether lost to our sight by the significant deformation and the extensive denudation which have taken place since.

At the close of the Old Red period, some old-land areas may have remained above water (marine or lacustrine is immaterial in this connection). Around any such areas stretched the horizontal Old Red strata. But that condition is not presented to us; for the Old Red strata were at some later time more or less tilted, especially around the Grampians; and in this disturbance the foundation rocks must have shared with their cover. It is true that in certain districts the Old Reds have been little disturbed; but the dips that I have seen in the neighbourhood of Moray Firth are quite sufficient to have required a significant disturbance in the old-land floor, as well as in the Old Red cover. Hence it seems impossible to make the peneplain that is indicated by the existing ridge-tops of the Highlands agree with either the pre-Old Red floor, or with the old-land areas that may have remained above water at the end of Old Red deposition. Just what view Messrs. Macnair and Reid hold on this question I do not gather from their essay; but my reasons for differing from Sir A. Geikie do not seem to me to exhibit misconception or general indefiniteness.

Whatever peneplain is recognizable in the sky-line of the

Highlands, I believe it to have been produced after the post-Old Red deformation of the region; probably long afterwards. In some places it may by accident agree with the Old Red floor; but as a whole it must differ from that floor, because the floor was generally deformed after the Old Red strata were laid on it. Such coincidence is against all probabilities. It is altogether unlikely that a peneplain of so ancient a date as Middle Palæozoic time should have stood nearly level and close to sea-level until so comparatively late a date as just before the uplift that allowed the erosion of the glens.

It may be noted that the peneplain of the Highlands is of more imperfect form, of more difficult recognition, and hence attended with more uncertainty in explanation, than various other uplifted and dissected peneplains that I have seen: for example, that of the Ardennes and Hunsrück, or that of southern New England, or of western Pennsylvania and Virginia. The Scotch example must have been a rugged one at the best. Local study may perhaps identify certain peneplain areas that were well developed by the denudation that formed them when the region stood lower, and that are not yet altogether obliterated by the denudation that has been initiated since the region has risen to about its present height. The record of such a study I would gladly see. At the same time it might be possible to infer by what sort of uplift the peneplain gained its present order of altitude; whether by an arching, such as Hayes and Campbell have described for the uplifted peneplain of the southern Appalachians (Nat. Geogr. Mag., Washington, vi, 1894, p. 63), or otherwise. It is perhaps to Scotch geographers rather than to Scotch geologists that one must look for a solution of this long-postponed problem; but the solution will be welcome whencesoever it comes.

Harvard University, *September*, 1896. W. M. Davis.

THE PARALLEL ROADS OF GLEN ROY.

Sir,—If the "parallel roads" are marine raised beaches, they were accumulated between daily tide-marks, and as such are sure to differ in character from beaches accumulated at more or less fixed levels. Secondly, if the beaches were marine and rocky, one or other form of *Littorina* could scarcely be absent, and *Littorinas* are practically indestructible. In the loose sand of one at least of the Devonshire raised beaches, these shells occur in perfect preservation; *Littorina obtusata* is also said to occur in the deposits on Moel Tryfaen. If, then, the beach-deposits of the parallel roads of Glen Roy still survive, and no trace of *Littorina* can be found in them, the fact is hard to explain in such a sheltered valley, on the hypothesis that the accumulations are of marine origin. If, in addition to the absence of *Littorina* the beaches show no signs of being accumulated between tide-marks, the difficulty of accepting their marine origin will be greater still. The best evidence of a raised-beach platform is its sloping towards the water as part of an old tidal strand. Can such inclined planes be detected in the case of the parallel roads of Glen Roy?

A. R. Hunt.